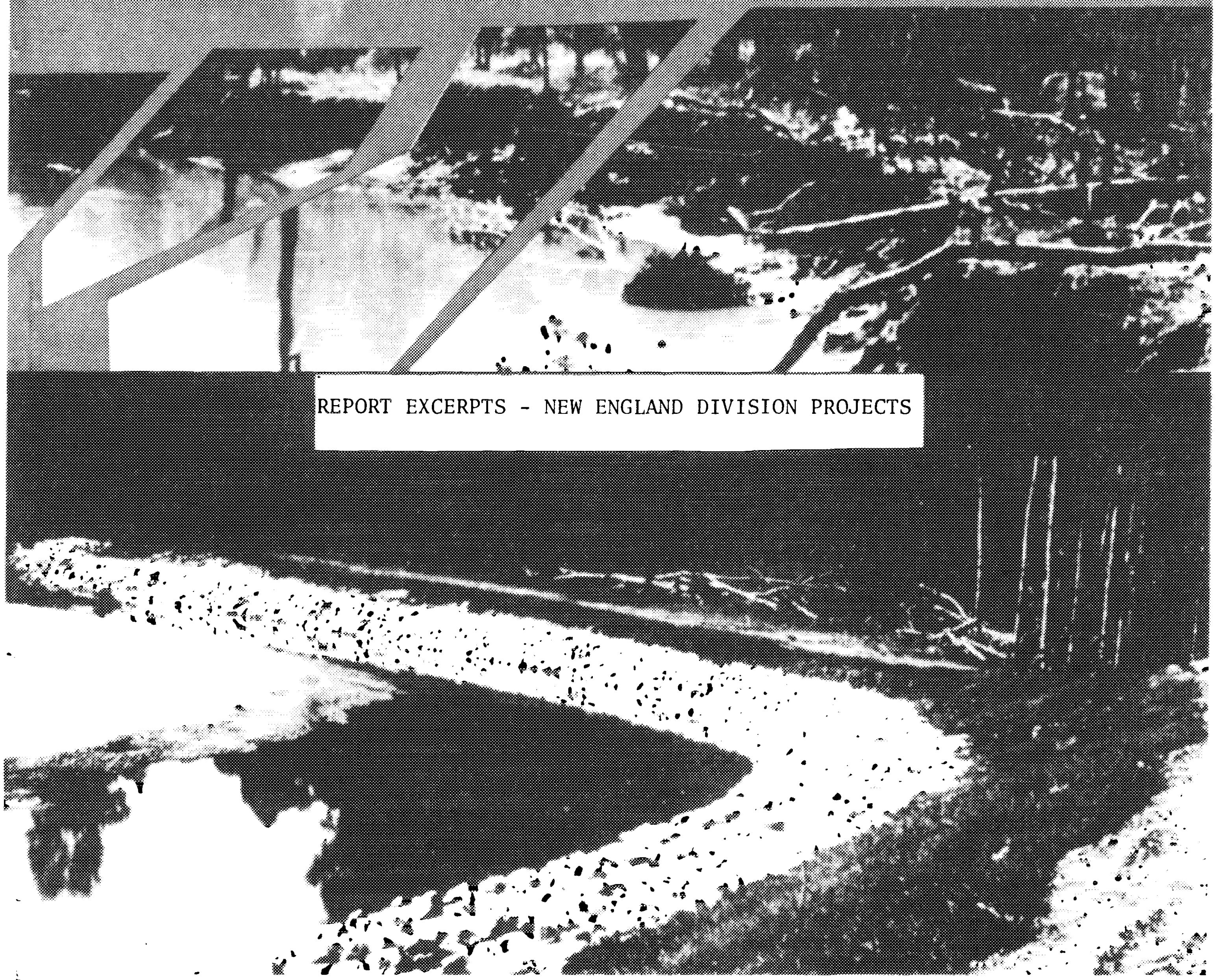
US Army Corps of Engineers

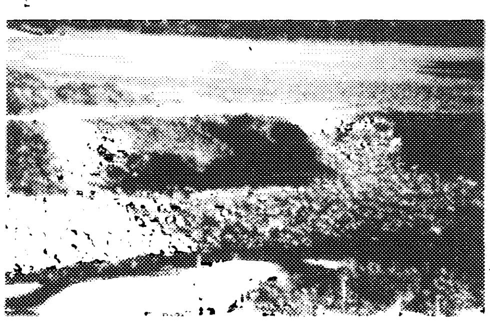
December 1981

FINAL REPORT TO CONGRESS

THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974
SECTION 32, PUBLIC LAW 93-251

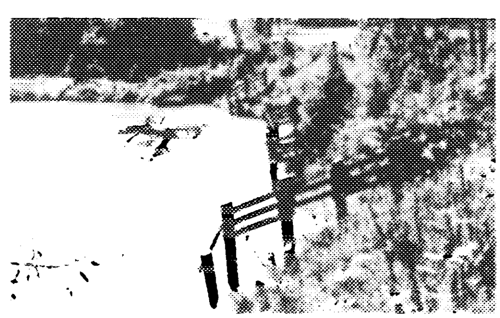


REPORT EXCERPTS - NEW ENGLAND DIVISION PROJECTS



Rock Toe With Tie-Backs

Precast Block Paving



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FINAL REPORT TO CONGRESS

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REPORT EXCERPTS

NEW ENGLAND DIVISION PROJECTS

U.S. ARMY CORPS OF ENGINEERS
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The Streambank Erosion Control
Evaluation and Demonstration Act of 1974
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EXCERPTS ON NEW ENGLAND DIVISION PROJECTS

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CONNECTICUT RIVER AT HAVERHILL, NEW HAMPSHIRE

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

CONNECTICUT RIVER AT HAVERHILL, NEW HAMPSHIRE
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

1. Project Name and Location. Haverhill Demonstration Site, Connecticut River, Haverhill, New Hampshire. Location map is shown on Plate 1.
2. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251.
3. Purpose and Scope. This report describes a demonstration project constructed by the New England Division to experiment with innovative techniques of streambank erosion control. It presents a description of the bank erosion problem and types of protection used and provides an evaluation of performance experience to date.
4. Problem Résumé. The left bank of the Connecticut River in the project area is 7 to 22 feet above the normal water level and is eroding at an average rate of 10 feet per year. Annual spring high water inundates the lower bank and the whole bank is inundated by unusually high spring runoff or floodflows. Erosion conditions at the site are typical of those caused by shear and eddy forces acting on alluvial soils on the outside of a bend in a meandering river. Ice also plays a role in the overall erosion process as do other less significant factors. The land being lost is prime farmland and there is likelihood that continued erosion would create an oxbow cutoff resulting in the isolation and loss of 30 acres of farmland.

II. HISTORICAL DESCRIPTION

5. Stream.

a. Topography. The project site lies in the northern portion of the Connecticut River Basin, the largest in New England. Draining in a southerly direction with its source in northern New Hampshire and mouth at Long Island Sound in Saybrook Connecticut, the Connecticut River extends more than 400 miles. The valley of the Connecticut River in the project area (approx. river mile 255) is bounded on the west by the Green Mountains of Vermont and on the east by the White Mountains of New Hampshire, with mountain peak elevations of over 4000 feet NGVD being quite common. Made up mostly of a glacial outwash plain, the valley floor is relatively narrow and of gentle terrain with elevations in the project area being about 400 feet NGVD. The normal stream gradient at the Haverhill site is about 0.1 foot per mile.

b. Geology. The geology of the Connecticut River Basin can be subdivided into two distinct periods: prior to and following continental glaciation. Preglacial history of the Connecticut River is quite diverse. Bedrock of the area consists of heavily folded and faulted metamorphic and igneous rocks. The metamorphic rocks include phyllites, schists, and gneisses. The igneous bodies are granite, granodiorite, and quartz monzanite with occasional intrusions of volcanic materials. The trends of major structural features in Vermont and New Hampshire are in a north-northeasterly direction. This coincides with the Connecticut River which probably follows an ancient drainage way.

Preglacial geology indicates extensive periods of erosion associated with the uplift of the Appalachian Mountains near the close of the Paleozoic Era, and with other periods when the land was emergent. It is assumed that the present topography was well established prior to continental glaciation, including a well developed soil layer with superimposed streams including their meandering patterns.

Massive continental glaciation wore the topography into the currently existing subdued forms. Highlands were rounded on the upper side facing the glacier and steepened on the lower side away from the glacier. Stream valleys were eroded and smoothed, sometimes into the classic V-shaped glacial valleys.

The retreating ice redeposited morainal materials over the entire surface of the area. Stagnant ice blocks and frontal moraines created lakes that became sites of further deposition. While the lakes were in existence, material was deposited as sandy and gravelly terraces consisting of deep, well drained alluvial soils developing in medium textured sediments, derived mainly from schist, gneiss, granite, slate and phyllite. The type of alluvial material forming the flood plains adjacent to the Connecticut River comprise the Hadley soils as classified by the US Department of Agriculture, Soil Conservation Service, and are water-laid deposits composed mostly of silty, fine sands and nonplastic fine, sandy silts. Soil core samples were collected and analyzed. The soil profile of the alluvial deposits is given on Plate 2.

c. Locality, Development and Occupation. The Haverhill, New Hampshire site is located in the upper Connecticut River valley, an area of rich alluvial soil which is the basis for one of the most productive farming areas in New England. Crops produced in the region include corn, hay and other assorted feed crops. The erosion site borders a large open field used primarily for corn.

Vegetation in the river valley is limited to small areas not in agriculture, including some woodlots and woodland along the river in areas not subject to streambank erosion. Woodland types include red and silver maple, elm, willow, cherry, poplar and alders. Some timber harvesting is done for lumber and firewood.

The population of Haverhill (3000 in 1970) and vicinity has declined in the last decade. Most of the labor force consists of people engaged in manufacturing, light industry, agriculture, and the tourist trade. There is also a significant amount of self-employed people in the region. The area at one time served as a distribution center for dairy farms in northern New Hampshire and Vermont.

d. Hydrologic Characteristics.

(1) Climatology. The relatively high elevations of the Green Mountains of Vermont and the White Mountains of New Hampshire have a marked influence on the temperature, precipitation and snow

cover of the Connecticut River Basin which lies in the path of the prevailing westerlies and air masses moving predominantly from the interior of North America. Generally west to southwest air flow brings the hot dry weather which is responsible for occasional summer droughts. In the winter months, high pressure weather systems from Canada bring frigid air into the basin. Precipitation is moderate to heavy and well distributed throughout the year. The annual mean temperature is about 45°F.

The average annual precipitation ranges from 36 inches in the main river valley to over 60 inches in the higher White and Green Mountains. Precipitation in the central and northern portions of the basin during the winter months is practically all in the form of snow. The average snowfall is from 50 to 70 inches in the valley to well over 100 inches in the mountains.

Three general types of storms produce precipitation over the basin: continental, coastal, and thunderstorms. Continental storms originate over the western and central portion of the United States and move generally in an easterly or northeasterly direction.

Tropical hurricanes, the most severe of the coastal storms originate in the South Atlantic or Caribbean Sea. They usually move in a westerly direction then northerly and may be deflected by high pressure zones to New England. Hurricanes have occurred in the summer and fall months. Extratropical storms generally originate or intensify near the middle Atlantic States, travel northward along the coastline and generally occur in autumn, winter and spring.

The third type of storm is the thunderstorm which can be produced by local convective activity during the warm humid days of the summer months or be associated with a frontal system moving across the basin.

The areal distribution of annual runoff follows a pattern somewhat similar to the annual precipitation in that it varies from 17 inches in the lower elevations to more than 40 inches in the White and Green Mountains. About 50 percent of the annual runoff occurs in the spring months of March, April and May. During this period combined rainfall runoff and snowmelt create an especially great chance of flooding.

(2) Streamflow. Flow conditions at the Haverhill site are best represented by the records of the US Geological Survey gage located 11 miles upstream on the Connecticut River at Wells River, Vermont (D.A. = 2644 square miles). The average flow at the gage during the summertime low flow season (July-October) is 3450 cfs and during the spring snowmelt months (April-May) is 15,635 cfs. The average annual peak discharge has been 33,100 cfs since completion of the last major upstream storage project in 1961. During the period from 1918-1950 the USGS recorded discharges in the Connecticut River at its gaging station in South Newbury, Vermont (D.A. = 2825 square miles) two miles downstream from the Haverhill site. Average discharge for the period of record was about 5000 cfs and a maximum discharge of 77,800 cfs was recorded on 19 and 20 March 1936. The recurrence interval of this peak discharge is estimated by statistical analysis to be about 90 years. By comparison, a minimum discharge of 198 cfs was recorded on 4 September 1934.

e. Channel Conditions. Under normal to moderate flow conditions the Connecticut River passes through the well defined channel it has cut through the valley floor alluvium (Plate 1 and Photo 1). The river takes a meandering course and, typically, is continually eroding its banks which are generally steep and caving and consist mainly of silty sands and sandy silts. Overtopping of the riverbank can occur whenever flows are in the order of 40,000 cfs, or on the average about every 3 to 5 years. At this particular site, high flows have passed over the top of bank, run down through an adjacent hayfield and rejoined the river at the next channel bend. The river is attempting to cut an oxbow which would create an island of about 30 acres of farmland.

Wilder Dam, a run-of-river hydropower project located about 38 miles downstream (river mile 217), creates a backwater effect at the Haverhill site under normal flow conditions. Water levels at the site, vary from 1 to 1.5 feet per day and range from elevation 386 to 383 feet NGVD over the weekly period due both to Wilder Dam operations and to the fluctuating flow releases from a series of upstream hydropower dams. During floodflows, the backwater effect of Wilder Dam diminishes and the hydraulic control becomes more nearly that of open channel characteristics. Water surface profiles for a range of flow conditions in the Wilder Dam pool are shown on Plate 3.

f. Environmental Considerations. The bank stabilization project is expected to result in a net improvement in wildlife habitat and water quality. The originally exposed riverbank was suited only as a seasonal nesting site for cliff swallows. The stabilized slope, re-vegetated above the protection structures with unmown grasses, legumes, vines and shrubs, provides beneficial habitat for a wider variety of wildlife. Bank stabilization and toe protection will also reduce siltation and localized turbidity in the Connecticut River.

6. Demonstration Site - Test Reach

a. Hydrologic Characteristics. The hydrologic characteristics are as previously stated. Hydrographs of average annual, annual peak and summertime flows for a 15-year period at the USGS gage at Wells River, Vermont are shown on Plate 4. A hydrograph of average daily discharges for the period of record is shown on Plate 5. Ice usually forms along the shore around mid-December (actual time of occurrence varies from year to year depending upon coldness of air temperature) and may or may not form an entire cover on the river. Photo 13 shows ice conditions at the project site in February 1981. The ice usually breaks up during the spring snowmelt runoff period in April.

b. Hydraulic Characteristics. As previously discussed in paragraph 5e, the demonstration site is situated in the upper reach of the Wilder Dam pool and is subject to regular daily and weekly water level and flow fluctuations due to both downstream and upstream hydropower operations (Plate 6). The stage-discharge rating curve is given on Plate 7. Field measurements made by the USGS near the toe of bank under normal flows ranging from 2,500 to 13,500 cfs indicate velocities less than 2 fps. Under floodflows in the order of 40,000 cfs local velocities have been calculated to be about 7 to 8 fps. Velocity distribution within the river channel cross section is unknown.

Wind generated waves are a relatively insignificant cause of bank erosion at the demonstration site due to extremely limited fetch. Also, boat generated waves play a minor role compared to other causative hydraulic factors as there is no commercial navigation and only a small amount of recreational boating traffic.

c. Riverbank Description.

(1) Bank Materials. Materials composing the banks and valley floor of the Connecticut River are classified as silty, fine sands and fine sandy silt. Alluvial deposits in the vicinity of Haverhill, New Hampshire are comprised mainly of the Hadley soils. Analysis of test results from the borings indicate that bank materials at the project site are water-laid deposits composed mostly of silty, fine sand (SM) and fine, sandy silts (ML). Soil classification and test results are given in Plates 8 and 9.

(2) Description of Vegetation. Vegetation in the test reach consisted of a narrow band of agricultural, native and weed grasses and some shrubs. Most of the riverbank was severely eroded to an almost vertical earth face. Adjoining the riverbank is an agricultural field, seasonally plowed for row crops. No significant trees existed along the riverbank in the eroded area.

(3) Erosion Conditions. Fifty-four sites along the banks of the Connecticut River in the pool behind Wilder Dam (river miles 217 to 259) are eroding. Rates of erosion as high as 13 feet of bank depth in a year have been documented by the US Soil Conservation Service. The main types of erosion being observed are sloughing, undercutting, and mass wasting, in that order, and the principal cause is shear stress associated with high streamflow. Other causes such as pool fluctuation, seepage, boat waves and overbank drainage play lesser roles in the overall erosion process. At the Haverhill site, the shear force is magnified by its location at the outside of a sharp riverbend, a phenomenon that also affects about 33 percent of the other erosion sites in the Wilder pool. Erosion prior to construction of the bank protection is shown on Photos 1 and 2. No previous attempts at erosion control are known to exist in the demonstration site area.

III. DESIGN AND CONSTRUCTION

7. General. Five different and somewhat novel methods of streambank protection were used in the Haverhill demonstration project. These included four types of revetment - gabion mattress, sand-cement filled bags, used rubber tire mattress and baled hay mattress - and a reach with no toe protection and only vegetative upper bank protection. All four revetment panels included vegetative protection on the upper bank. The arrangement of the various test panels are shown on Plate 10.

8. Basis for Design.

a. Lower Bank Protection. The primary goal in selecting the types of protection to be utilized was to gain experience with new and innovative methods of streambank erosion control. Gabion mattresses and sand-cement filled riprap bags were selected because of their commercial availability and the New England Division's desire to gain field experience with them. Rubber tire matting and baled hay were selected on the basis that they are readily available materials and on the premise that they would require relatively simple construction techniques that local government agencies and private land owners could employ. The panel with no toe protection was selected to determine whether simply cutting the eroded bank back to a uniform slope would result in a stable section. In effect, the panel was to serve as a control against which to gage the necessity for and effectiveness of lower bank (toe) protection.

b. Upper Bank Protection. Upper bank protection was provided by a series of test areas of various mixes of grasses, legumes, vines and shrubs. In general, vegetation was used as an alternative to more expensive structural measures in the portion of the bank above the normal high water line, and also as a more natural appearing bank cover in the project's rural setting. Selection of plant species was based on knowledge of suitable native and adapted species types commercially available in the region. Additional technical assistance was provided by the Soil Conservation Service (SCS), US Department of Agriculture. Three methods of mulching were also compared: excelsior fiber mats, hay with netting, and wood chips. Grasses were selected to provide a thick vegetative mat that protects the soil surface from the erosive effects of rainfall and high stage flows and to buffer the impact of floating debris, induce minor silt deposition and reinforce and stabilize the soil surface through extensive fine texture roots. Shrubs and vines, planted as container grown, healthy, young plants, provide less rapid soil protection but better wildlife cover and food potential.

Plates 10 and 11 list the plant species used and show their location in the project. In general, the experimental grass mixes were chosen on the basis of rapid establishment, suitability for growth with little or no maintenance, and adaptability to periodic inundation. Legumes were added to some mixes for supplemental nitrogen. Shrub species were chosen for wildlife value and adaptability to periodic inundation. Vines were chosen for their hardiness, woody growth and ability to provide rapid low cover.

9. Construction Details. The total project length is 2600 feet. Five techniques of bank protection, described below and shown on Plates 10 and 12 were installed in approximately 500-foot reaches along the bank.

a. Reach 1. Gabions, 3 feet wide by 12 feet in length were wire laced together and anchored to the slope in order to form a twelve-inch thick protective rock mattress. The mattress was constructed from an underwater dumped gravel toe on a 1.75H to 1V graded slope to a point 3 feet vertically above the normal water line. Filter fabric (Typar Spunbonded Polypropylene, Style 3421) was used under the gabions along this reach. The bank above was dressed to its natural slope (1.5H to 1V) and seeded. See Photo 3.

b. Reach 2. A matting of interlocked used rubber tires was placed on the underwater slope from the toe up to a point 3 feet vertically above the normal water line. The tires were placed on a 1.25H to 1V slope and anchored to the bank. Anchoring was accomplished using a steel reinforcing rod driven into the bank at the center of the tire, which was then filled with concrete. This was done only at specific tires spaced at 12-foot intervals along the top and bottom of the matting. Tires in the first half of the reach (2A) were filled with crushed stone while tires in the remainder of the reach (2B) were filled with random fill material. The bank above was dressed to its natural slope (1.25H to 1V) and vegetated. See Photos 4 and 5.

c. Reach 3. Sand and cement filled reinforced paper riprap bags (Hudson's Reinforced Paper Riprap Bags) were placed against the bank on a 2H to 1V slope from the underwater toe up to a point 3 feet above the normal waterline. Filter fabric was placed under the sand and cement riprap bags along this reach. The upper bank was formed to a 2H to 1V slope and vegetated. See Photo 6.

d. Reach 4. The bank was reformed to a 2H to 1V slope and overlaid with baled hay which is contained by an anchored wire mesh. Filter fabric was used under the hay bales only in the first half of the reach (4A). The upper bank was formed to a 2H to 1V slope and vegetated. During construction a change was made substituting screw earth anchors for the specified smooth rod anchors in order to remedy the problem of flotation created by the buoyancy of the hay bales.

e. Reach 5. The final section remained in its original condition below the waterline. The upper bank was formed to a 2H to 1V slope and vegetated.

10. Costs. Total cost and unit cost on a linear foot basis for each of the test reaches in the Haverhill project are shown in the following table. These costs were developed based on contractor bid items and do not include 6 and 7 percent markups for Corps of Engineers engineering and design, and supervision and administration, respectively.

Test Reach	Total Cost (dollars)	Cost Per Linear Foot (dollars)
1	47,500	95
2A	13,600	54
2B	13,800	55
3	50,000	100
4A	25,000	100
4B	24,100	96
5	22,200	44

Costs are for the time of project construction which was completed in September 1979. The cost of gabion protective dividers has not been included in the cost of each reach. Total contract cost for the entire project including all facets was about $250,000.

IV. PERFORMANCE OF PROTECTION

11. Monitoring Program. The elements of the monitoring program are summarized on Plate 13. The site was monitored for one year beginning in November 1979, just after completion of construction. Monitoring was discontinued after one year due to inadequate funding. Baseline topographic surveys were taken the year before and just prior to construction. Additional cross-section surveys of Reach 5 (which failed) and of some minor washouts caused by overland runoff were taken in the fall of 1980 (Plate 14 and Photo 12). Settlement monuments were also checked at this time to determine if any change had occurred since post construction readings were taken; no significant change was noted. No significant floods have occurred during the monitoring period; the Connecticut River has not reached bankfull conditions.

Velocity measurements were taken by the US Geological Survey during three visits to the site. These readings, taken during low, moderate, and higher flows experienced since construction, are shown on Plate 15. Visual inspections of the project were conducted by NED in the fall of 1979 and in spring and fall 1980. Pertinent findings were noted in periodic inspection reports which were submitted to the Waterways Experiment Station. Ground level photographs were taken during these inspections (Photos 7 through 12) to document changed conditions. Additionally, CRREL inspected the site in February 1980 to observe and report on winter ice conditions (Photo 13). Material tests of bank soils (Plates 8 and 9) were accomplished prior to construction and materials used in construction were tested on an as-needed basis.

12. Evaluation of Protection Performance.

a. Lower Bank Protection. The maximum discharge experienced to date by the completed project occurred on 11 April 1980 and was estimated to be about 19,400 cfs (which is substantially less than the mean annual flood (33,100 cfs). The lower bank protection at the site was overtopped by about 3 feet during this flow. Some minor scouring was noted in the zone of overtopping on the vegetated upper bank, especially where shrubs with wood chips had been placed. Reach 5, which has no toe protection, suffered considerable erosion (Photo 12). Some of the earth filling in the rubber tires in Reach 2B has washed away with minor settlement being noted. Additionally, some rusting was noted on metal tire strapping below the water surface. Limited bulging and voids were observed in the baled hay protection. Sand-cement filled bags are deteriorating as intended, however, the sand-cement itself is starting to erode. Gabion protection and stone filled auto tires were found to be in good condition. Overall, the protective systems are performing satisfactorily with the exception of nontoe-protected panel (Reach 5) and the earth filled used tire matting (Reach 2B).

b. Upper Bank Protection. Some limited gully erosion on the upper bank, due to concentrated surface runoff from the adjacent farm field, has occurred but it poses no serious threat to the overall project. Since no significant river flows have occurred following completion of project construction and planting of upper bank protection, complete evaluation of the effectiveness of various plants in controlling erosion is not possible. The vegetation has become well established and has effectively acted to reinforce the soil surface and resist rainfall. However, the long term effectiveness of the protective works will not be known until significantly large river flows occur.

13. Rehabilitation. No rehabilitation has taken place at the project. However, plans and specifications are being developed which include the use of 12-inch thick gabion mattresses to provide lower bank protection in Reach 5 (no toe protection), which has failed. Repair

work consisting of grouted rock gutter drains is planned to correct minor gulley erosion caused by concentrated surface runoff at two locations. If the loss of earth fill in the used auto tires continues, some stabilizing action in that reach may be necessary in the future.

14. Conclusions. Preliminary evaluations in the absence of experienced high flow conditions indicate several general conclusions.

a. Lower Bank Protection. Toe protection is an essential ingredient of any successful streambank protection. This is evidenced by the failure of Reach 5, which was the only one constructed without toe protection. Stone fill should be used in rubber tire mattress instead of random earth filling. This conclusion is based on the superior performance of Reach 2A. No performance difference was observed between reaches with and without filter cloth. Noncorrodable banding should be utilized in rubber tire mattresses. Additionally, a method for controlled conveyance of overland surface runoff to the river should be provided.

b. Upper Bank Protection. Seed cover on upperbank is best established in the spring, so that a full growing season is available for root development and top growth. Fall planting requires a larger percentage of winter rye or other nurse grass to control erosion until the perennial grasses become well established. Mulching grass seeded areas with hay and plastic netting works as well if not better than the commercial excelsior matting. The added per square foot cost of nursery grown shrubs and vines may not justify their use for erosion control, as they take too long to establish adequate cover, and the root systems do not develop the fine network of roots adequate to control surface erosion. Wood chips or bark mulch, commonly used to control surface erosion and retain soil moisture around plants, are not reliable on a 2:1 riverbank slope; high water rapidly washes mulch away, leaving the soil surface exposed to riverflow or overbank erosion. Shrub planting areas at the top of bank have not shown any soil or mulch erosion.

Short term performance evaluation indicates that Siberian Dogwood, *Cornus alba siberica*, Redosier Dogwood, *Cornus stolonifera* and American

Bittersweet, Celastrus americana provided the best growth and cover of the shrubs and vines used. Of the seed mixes, the best cover has been provided by mixtures #1 and #3, both dominated by Reed Canary grass, Phalaris arundinacea and Kentucky 31 Fescue, Festuca elatior arundinacea (Plate 11).

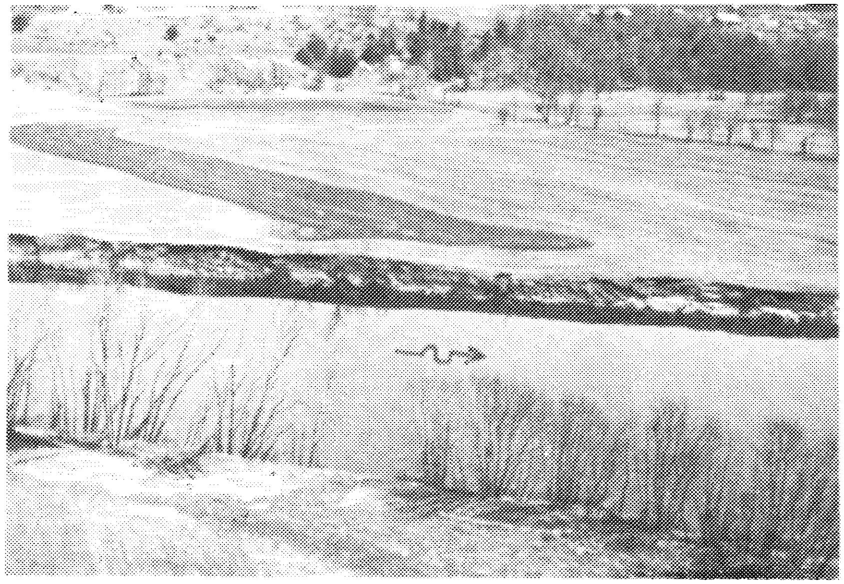


PHOTO 1
AERIAL VIEW FROM WEST
APRIL 1978

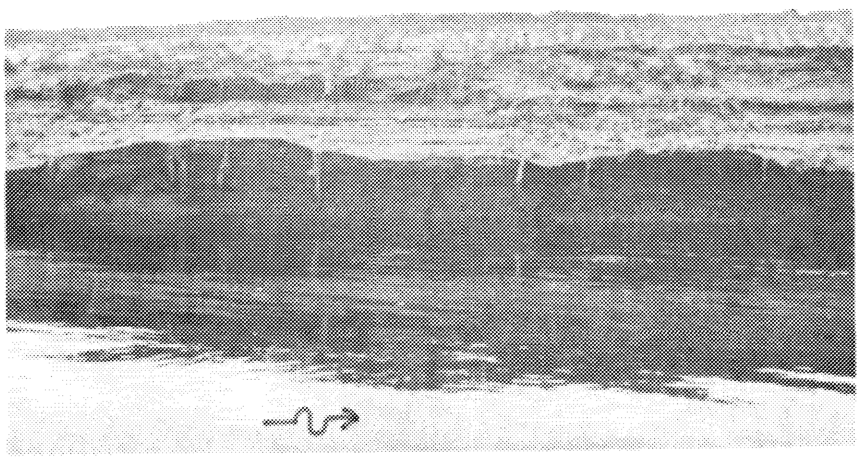


PHOTO 2
BOAT VIEW FROM WEST
MAY 1977

HAVERHILL PROJECT
PRE-CONSTRUCTION

PHOTOS 1 AND 2

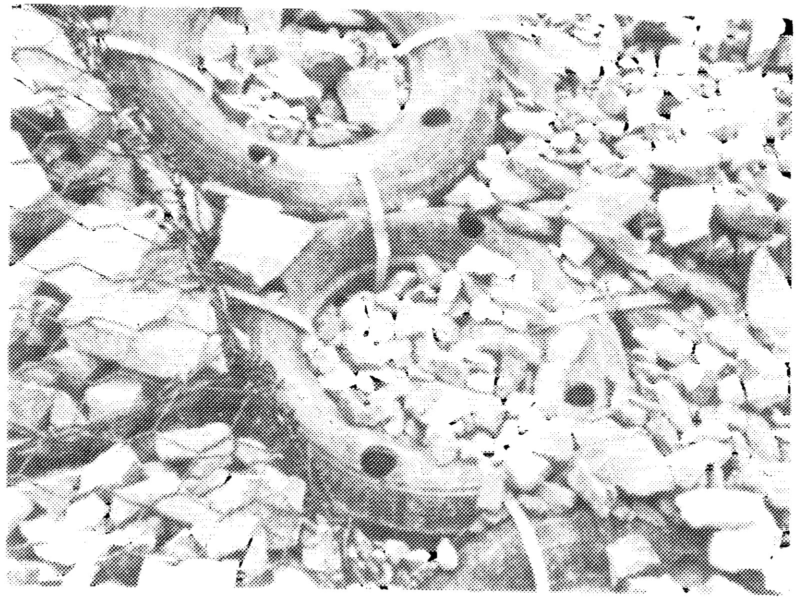


PHOTO 3
REACH 1
JULY 1979

PHOTO 4
REACH 2A
JULY 1979

HAVERHILL PROJECT
DURING CONSTRUCTION

PHOTOS 3 AND 4

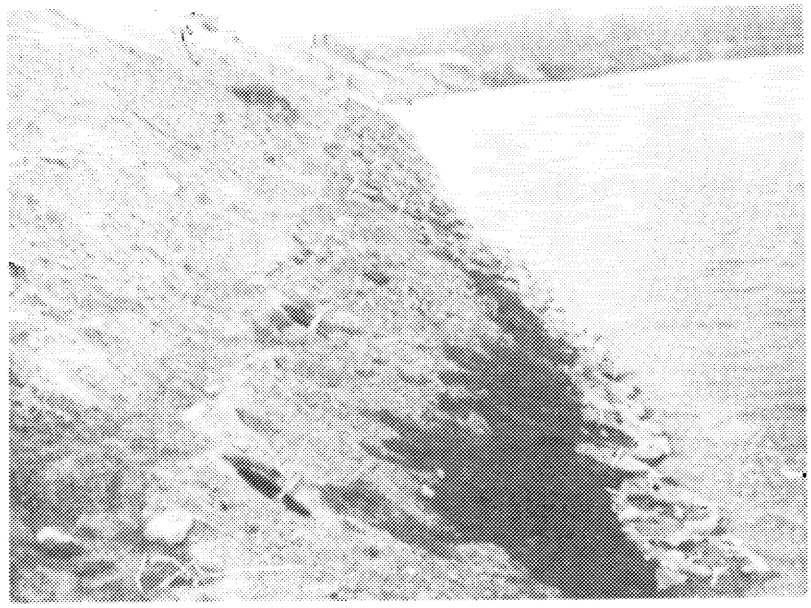


PHOTO 5
REACH 2B
JULY 1979

PHOTO 6
REACH 3
JULY 1979

HAVERHILL PROJECT
DURING CONSTRUCTION

PHOTOS 5 AND 6

PHOTO 7
REACH 1
MAY 1980

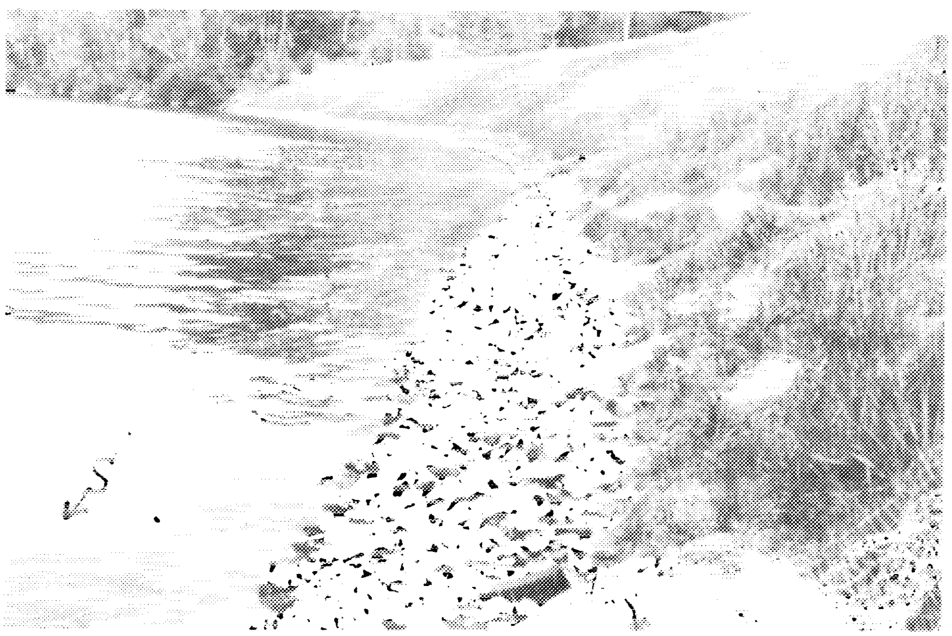


PHOTO 8
REACH 2B
MAY 1980

HAVERHILL PROJECT
POST CONSTRUCTION

PHOTOS 7 AND 8

PHOTO 9
REACH 2B
MAY 1980

PHOTO 10
REACH 3
MAY 1980

HAVERHILL PROJECT
POST CONSTRUCTION

PHOTOS 9 AND 10

PHOTO 11
REACH 4
MAY 1980

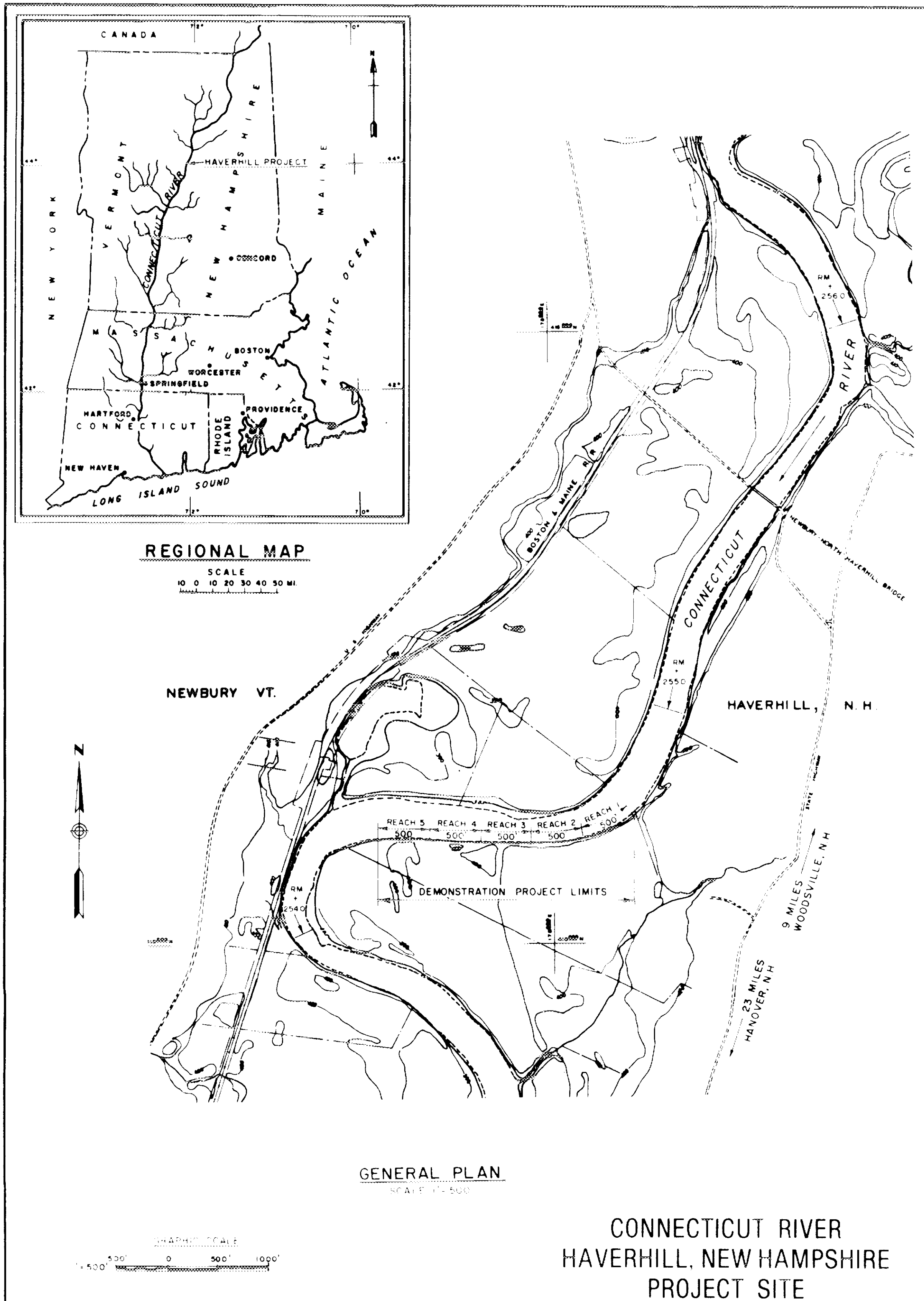
PHOTO 12
REACH 5
MAY 1980

HAVERHILL PROJECT
POST CONSTRUCTION

PHOTOS 11 AND 12

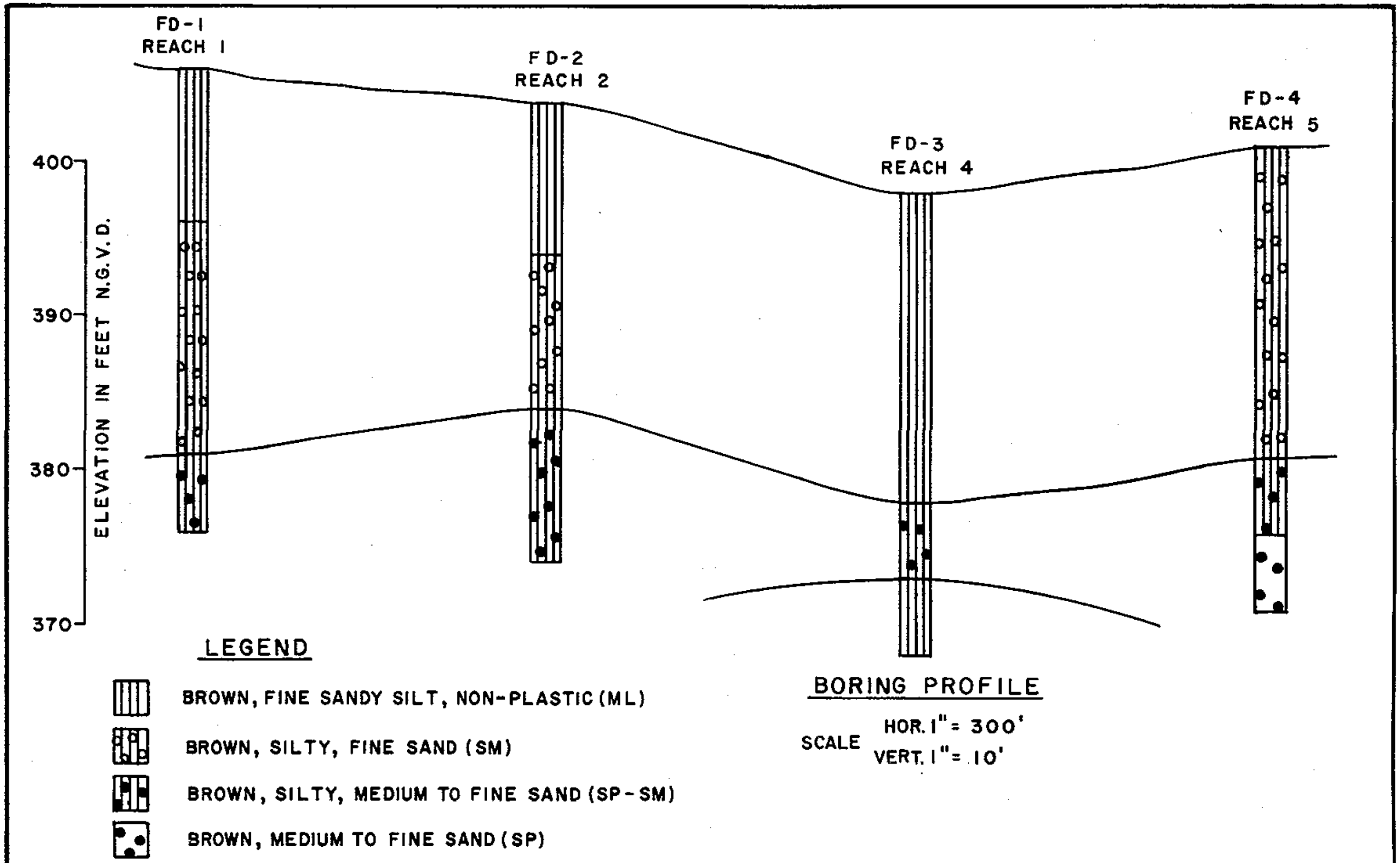
ICE CONDITIONS
20 FEBRUARY 1981
VIEW LOOKING UPSTREAM

PHOTO 13



CONNECTICUT RIVER
HAVERHILL, NEW HAMPSHIRE
PROJECT SITE

PLATE 1



GEOLOGIC SECTION

PLATE 2

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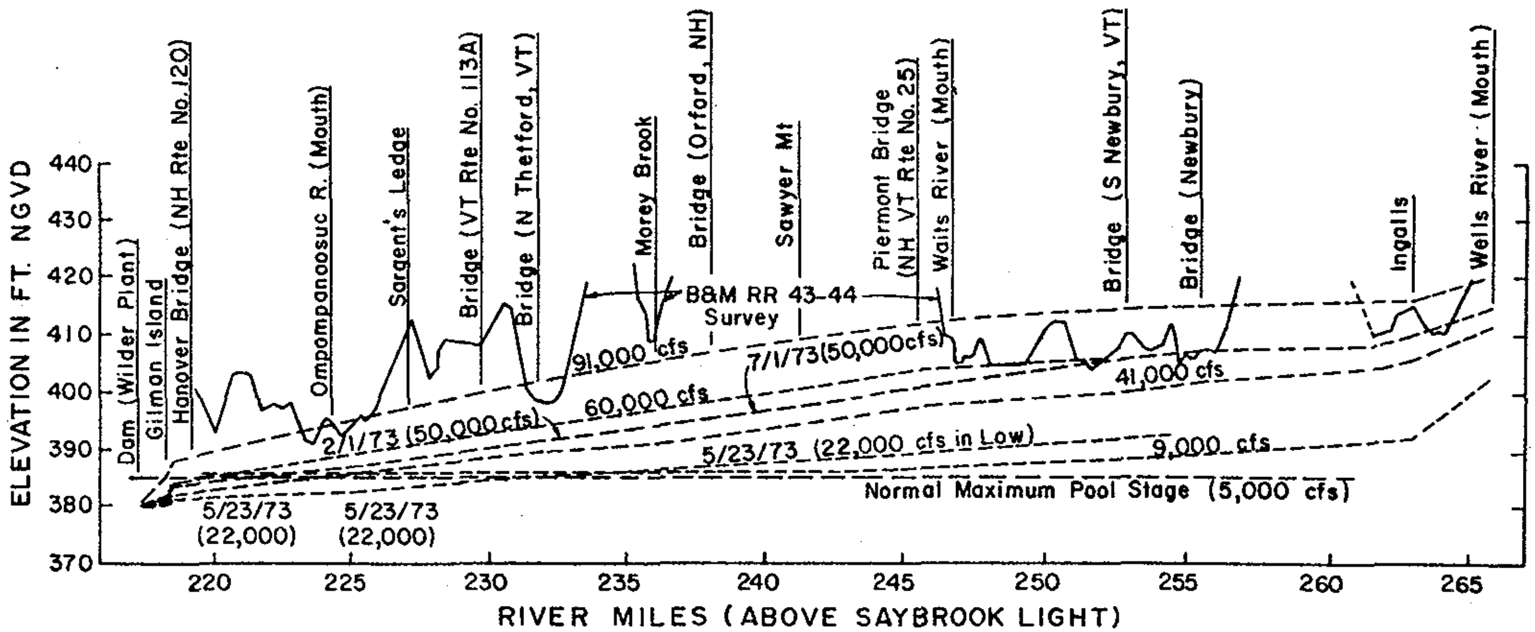
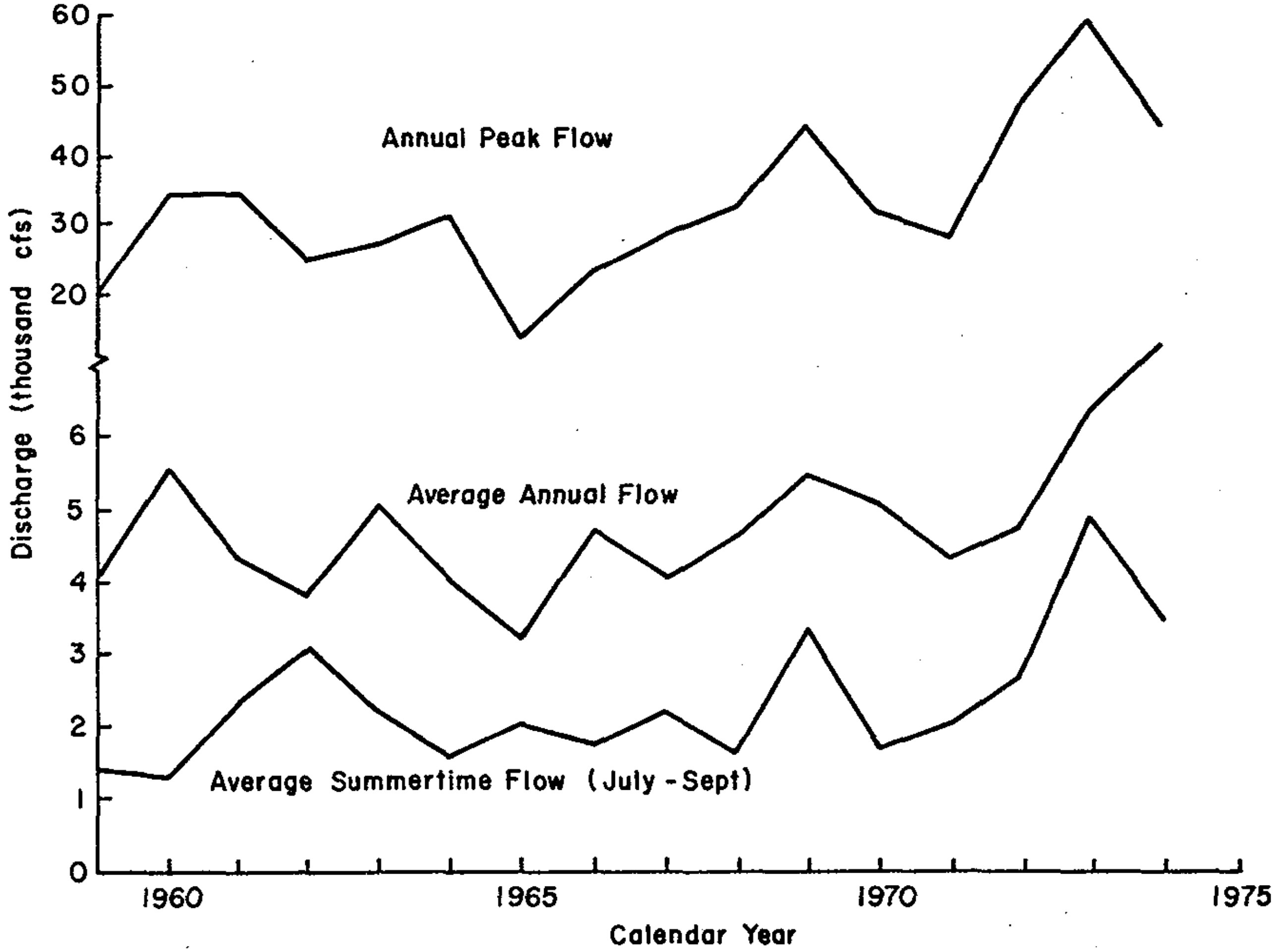


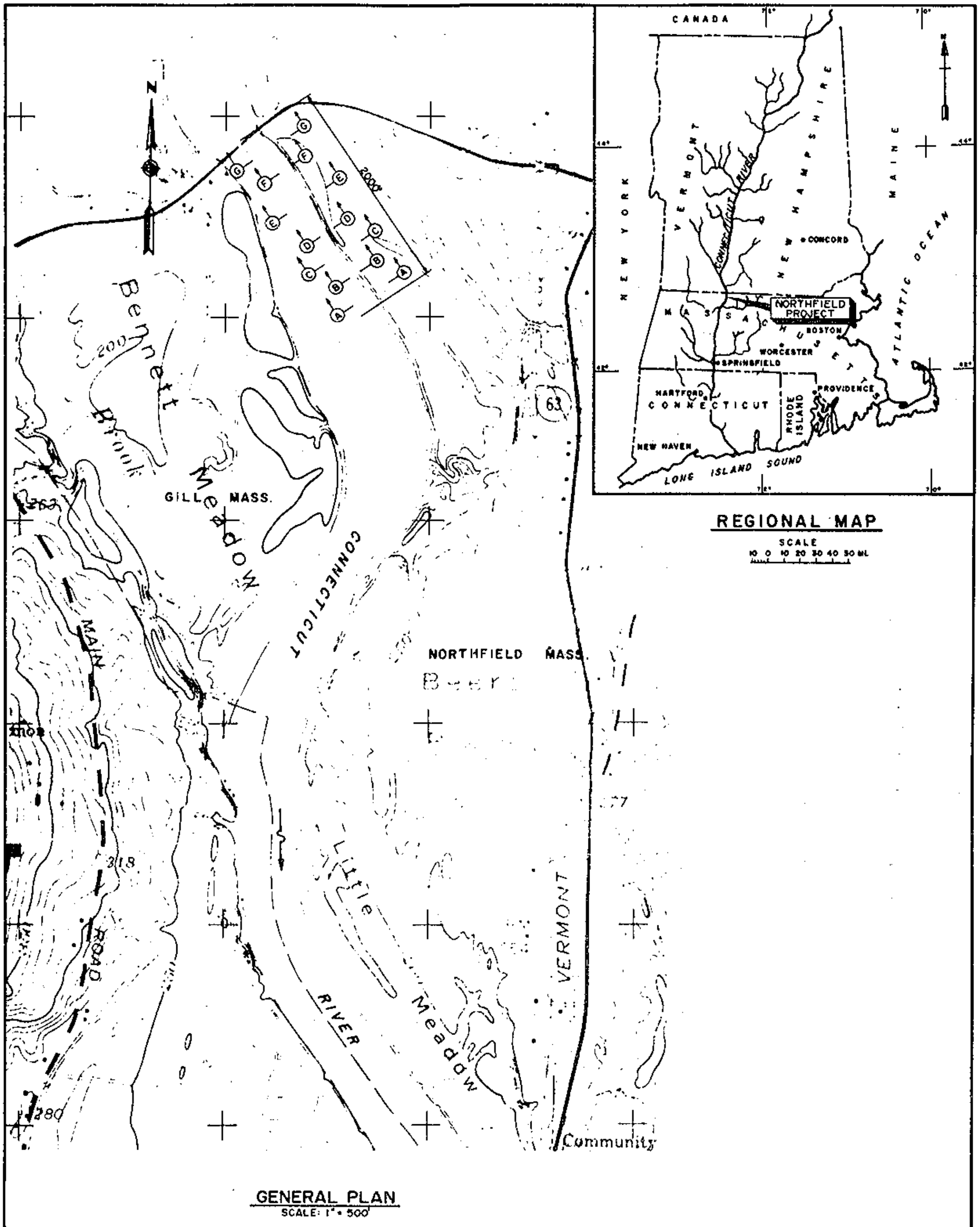
CONNECTICUT RIVER
WILDER POOL
WATER SURFACE PROFILE



CONNECTICUT RIVER
WELLS RIVER, VERMONT
USGS GAGE

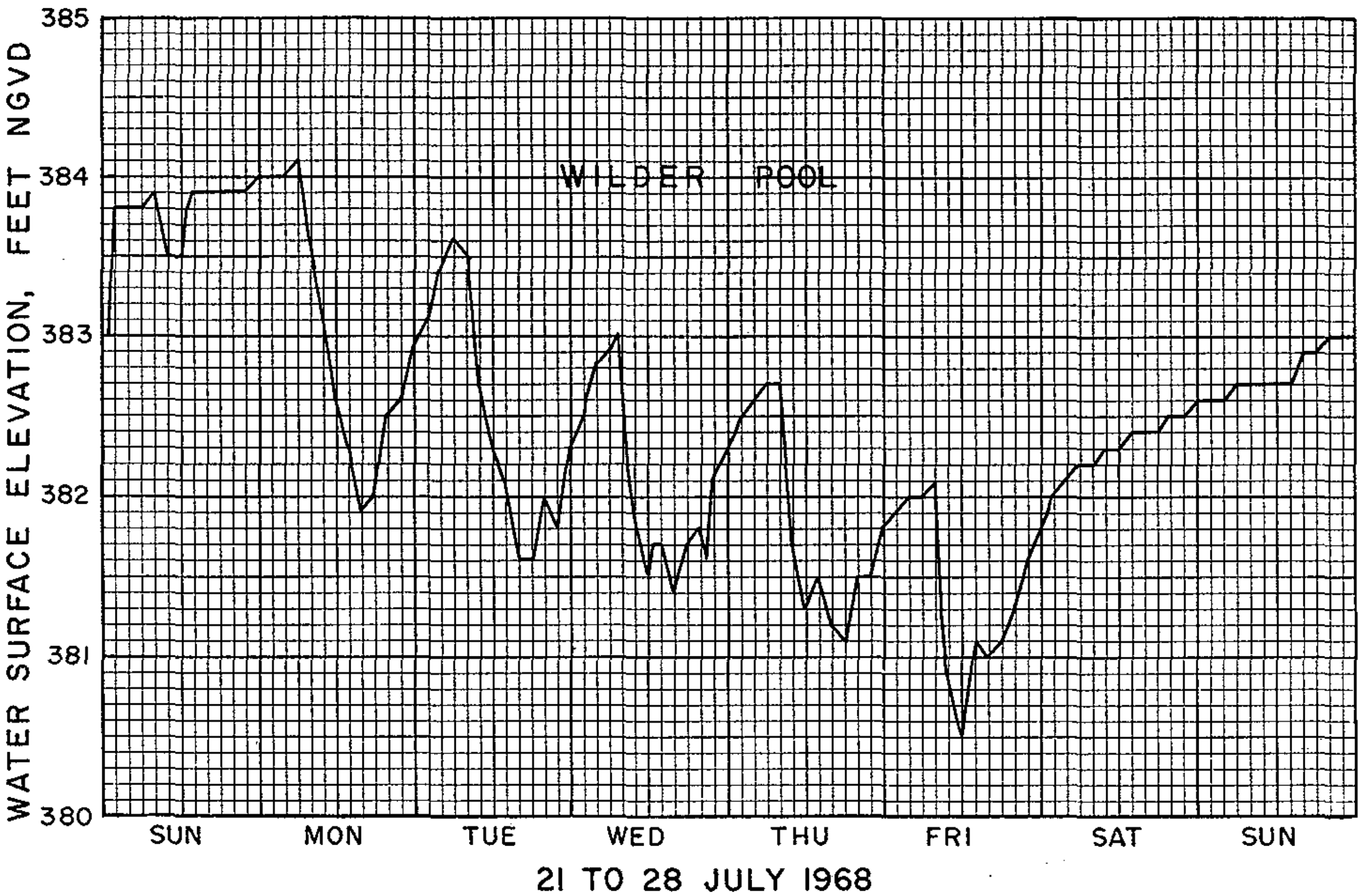
G-54-25

PLATE 4



CONNECTICUT RIVER BASIN
NORTHFIELD, MASSACHUSETTS

PLATE 1

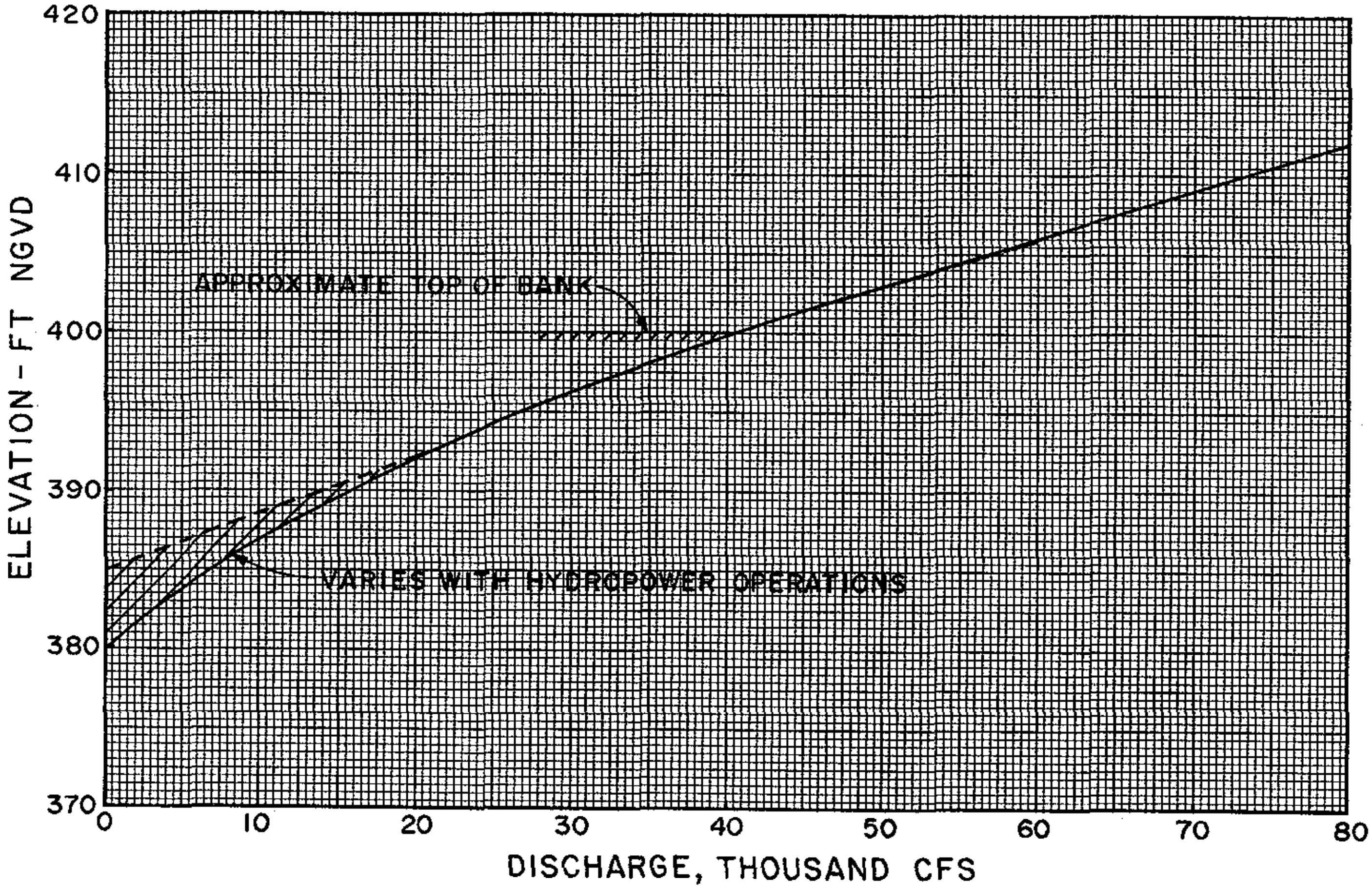


WILDER POOL FLUCTUATIONS

G-54-27

PLATE 6

PLATE 7



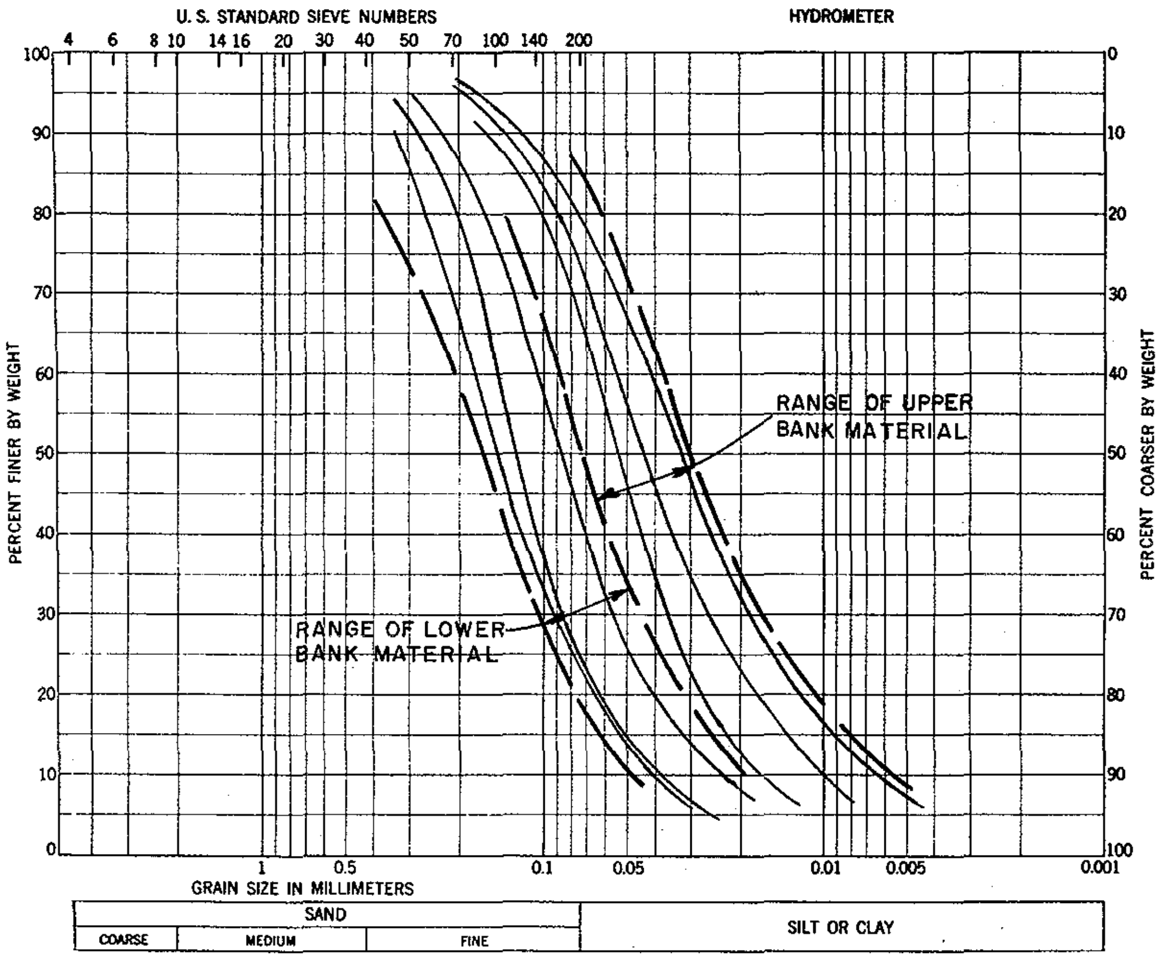
APPROXIMATE STAGE-DISCHARGE RELATIONSHIP
HAVERHILL DEMONSTRATION PROJECT

G-54-28

REACH NO.	EXPL. NO.	TOP ELEV. FT.	SAMPLE NO.	DEPTH FT.	SOIL SYMBOL	MECHANICAL ANALYSIS				ATT. LIMITS		SPECIFIC GRAVITY	NAT. WATER CONTENT % DRY WT	
						GRAVEL %	SAND %	FINES %	D_{10} mm.	LL	PL		TOTAL	-NO4
1	FD-1	406±	J-1	0.0- 5.0	ML	0	32	68	0.015	NP	NP	2.73	16.9	16.9
			J-3	10.0-15.0	SM	0	67	33	0.035	NP	NP	2.68	11.4	11.4
			J-6	25.0-30.0	SP-SM	3	89	8	0.10	NP	NP	2.71	16.3	-
2	FD-2	404±	J-1	0.0- 1.5	ML	0	20	80	0.0066	34	29	2.68	27.0	27.0
			J-3	11.5-15.0	SM	0	58	42	0.026	NP	NP	2.65	10.3	10.3
			J-6	26.5-30.0	SP-SM	0	94	6	0.10	NP	NP	2.70	21.9	21.9
4	FD-3	398±	J-1	0.0- 5.0	ML	0	38	62	0.018	NP	NP	2.68	16.6	16.6
			J-3	10.0-15.0	ML	0	25	75	0.012	NP	NP	2.72	34.0	34.0
			J-5	20.0-25.0	SP-SM	3	89	8	0.080	NP	NP	2.68	21.6	-
			J-6	25.0-30.0	ML	0	5	95	0.014	NP	NP	2.71	27.5	27.5
5	FD-4	401±	J-1	0.0- 1.5	SM	0	76	24	0.040	NP	NP	2.68	13.5	13.5
			J-4	15.0-16.5	SM	0	78	22	0.040	NP	NP	2.69	29.6	29.6
			J-6	25.0-26.5	SP	0	96	4	0.15	NP	NP	2.69	25.7	25.7

SOIL CLASSIFICATION DATA

PLATE 9



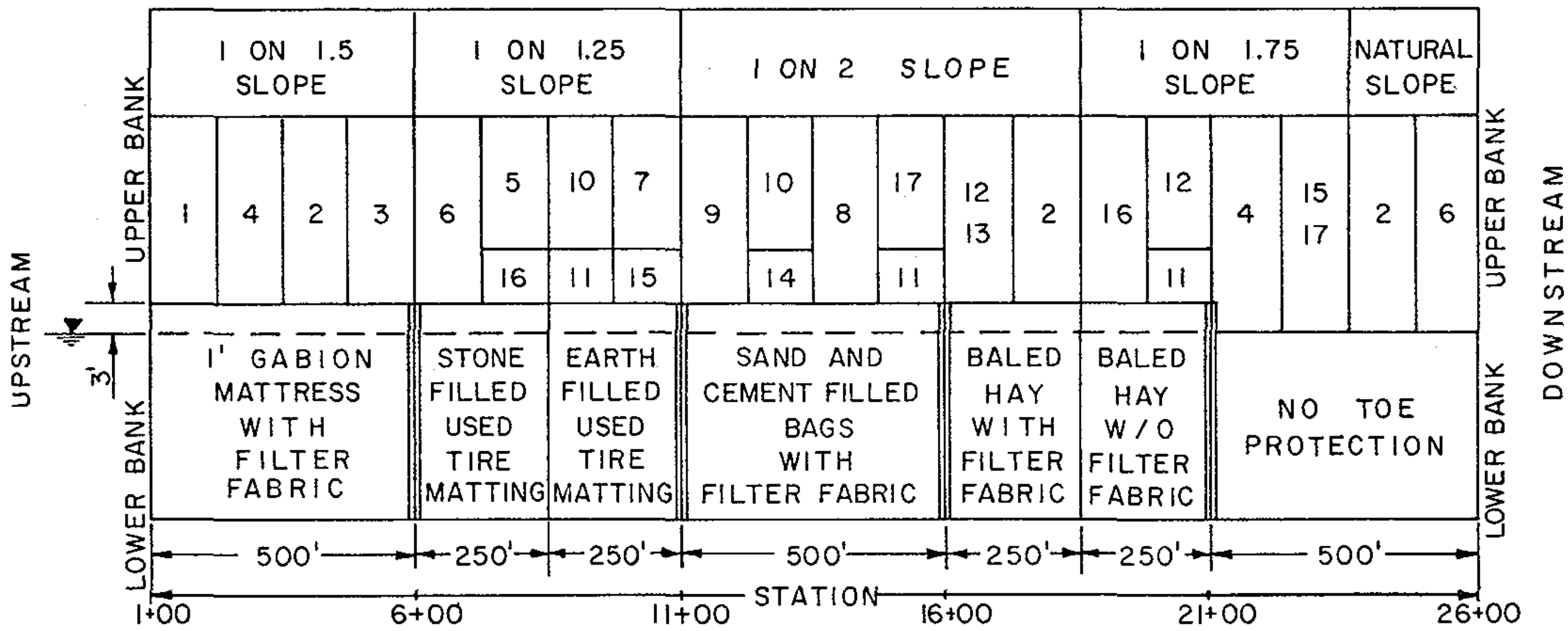
GRADATION CURVES
EXISTING BANKS MATERIALS

G-54-30

G-54-31

NOTE:

GABION PROTECTIVE DIVIDERS LOCATED AT STA'S. 6+00, 11+00, 16+00 AND 21+00.



SEE PLATE 11 FOR LIST OF UPPER BANK VEGETATION TYPES

CONNECTICUT RIVER
HAVERHILL, NEW HAMPSHIRE
PROTECTIVE MEASURES

PLATE 10

SEED MIXTURES

1 REED CANARYGRASS
KENTUCKY 31 FESCUE
REDTOP

2 REED CANARYGRASS
CREEPING RED FESCUE
REDTOP

3 REED CANARYGRASS
KENTUCKY 31 FESCUE
BIRDSFOOT TREFOIL

4 CROWNVETCH
KENTUCKY 31 FESCUE
CREEPING RED FESCUE

5 FLAT PEA
KENTUCKY 31 FESCUE

6 CROWNVETCH
FLAT PEA
KENTUCKY 31 FESCUE

7 BIRDSFOOT TREFOIL
CREEPING RED FESCUE

8 CREEPING RED FESCUE
BIRDSFOOT TREFOIL
REDTOP

9 KENTUCKY 31 FESCUE
CREEPING FESCUE
REED CANARYGRASS
REDTOP

10 KENTUCKY 31 FESCUE
CREEPING RED FESCUE
REDTOP

SHRUBS AND VINES

11 PURPLEOSIER WILLOW

12 SIBERIAN DOGWOOD

13 REDOSIER DOGWOOD

14 SUMMERSWEET

15 AMERICAN BITTERSWEET

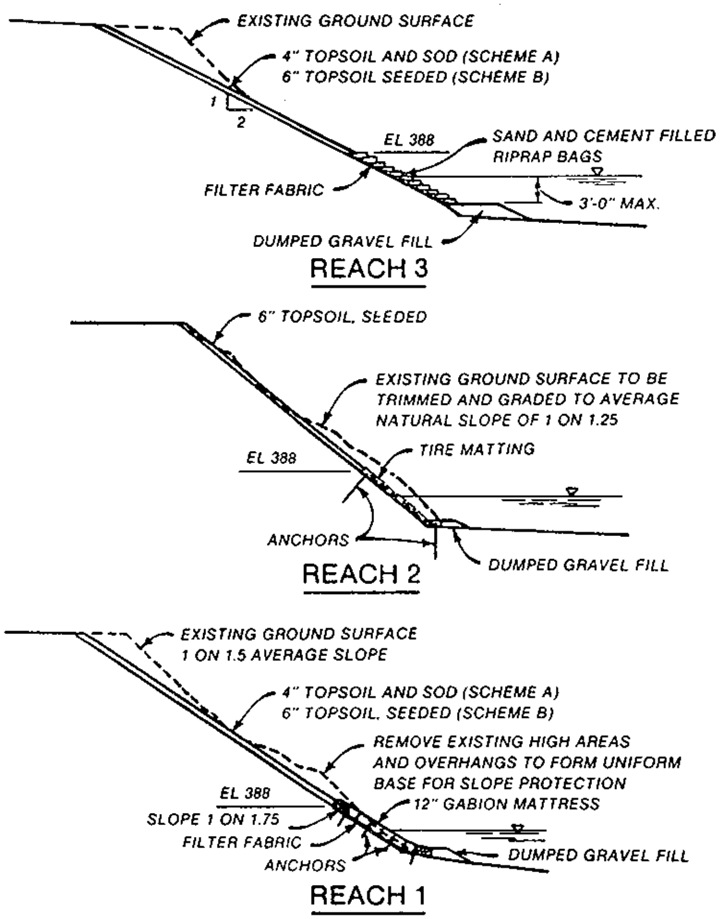
16 VIRGINIA CREEPER

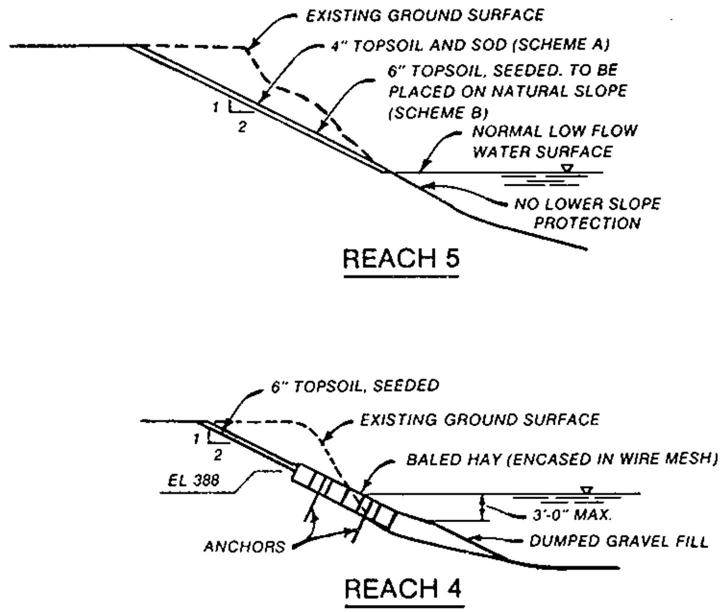
17 HALL'S HONEYSUCKLE

NOTE: NUMBERS ARE KEYED TO PANELS ON PLATE 10

UPPER BANK VEGETATION
HAVERHILL DEMONSTRATION PROJECT

PLATE 11





NOTE: WHERE SCHEMES A AND B ARE INDICATED ON SECTIONS: SCHEME A INDICATES THE FIRST 250' OF A PARTICULAR REACH AND SCHEME B INDICATES THE OTHER 250'.

TYPICAL SCHEMES

SCALE
5 0 5 10 FT

CONNECTICUT RIVER
HAVERHILL, NEW HAMPSHIRE
PROTECTION SCHEMES

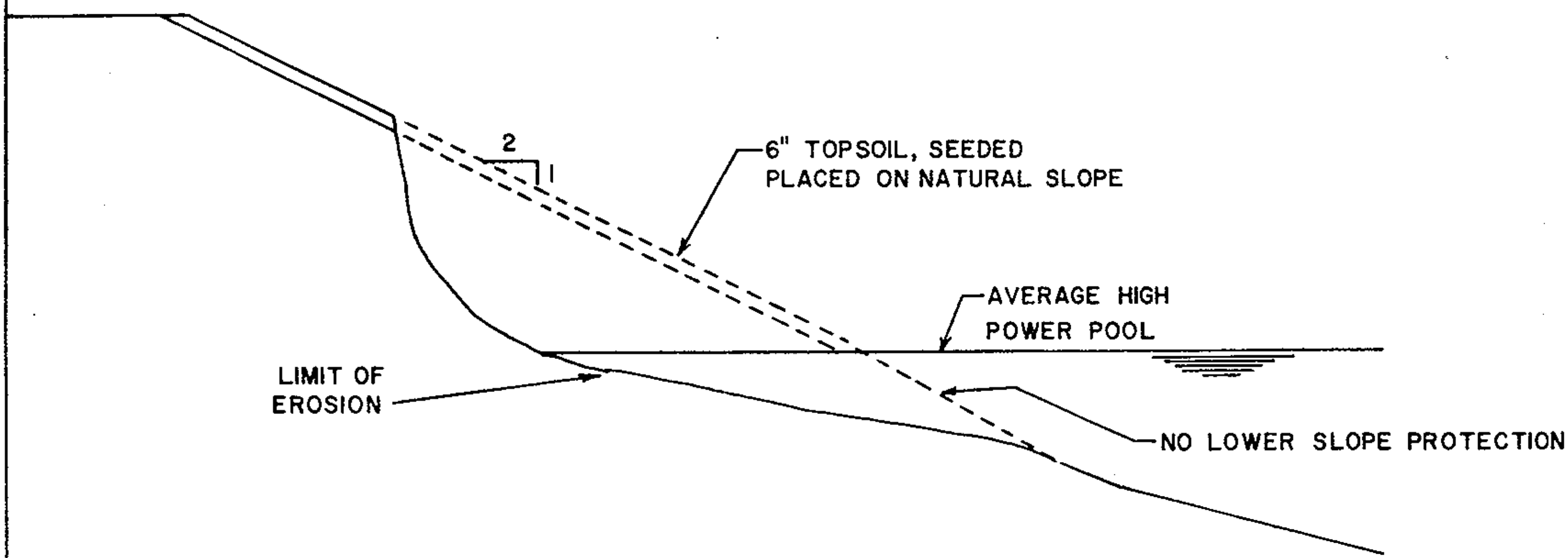
G-54-33

PLATE 12

FIELD DATA OF PHYSICAL FEATURES	FREQUENCY
1. Detailed topographic survey of bankline from thalwag to 15 feet beyond top of bank.	Taken the year before and just prior to construction.
2. Cross sections of bankline extending from thalwag to 15 feet beyond top of bank.	Developed for project design and taken as needed for repair and reconstruction work.
3. Settlement monuments checked for vertical and horizontal movements.	Checked just after construction and then on as needed basis.
4. Velocity measurements at toe of slope and 40 feet riverward and recording of discharge and water surface elevation.	Taken during low, medium, and higher flow periods.
VISUAL OBSERVATIONS	
1. Aggradation-degradation processes.	Semi-annually for all visual observations.
2. Erosion and river conditions.	
3. Changes in aquatic and terrestrial habitat.	
4. Changes in upper slope vegetation.	
5. Changes in structure integrity and material durability.	
6. Surface current flow patterns.	
MATERIAL TESTS	
1. Borings of bank material.	Once during preconstruction period.
2. Mechanical analysis of riverbank material.	
3. Classification of bank material.	
4. Specific gravity, Atterberg limits, hydrometers and water content of bank material.	
5. Analysis of construction materials when appropriate.	As needed during construction.
PHOTOGRAPHY	
1. Aerial photography	Preconstruction photos taken at site.
2. Ground level periodic photographs taken at predetermined locations.	Taken semi-annually beginning at the completion of construction.

CONNECTICUT RIVER
HAVERHILL DEMONSTRATION SITE
MONITORING PROGRAM

PLATE 13



CONNECTICUT RIVER
HAVERHILL, NEW HAMPSHIRE
FAILURE OF REACH 5

G-54-35

PLATE 14

PLATE 15

	Visit #1				Visit #2				Visit #3			
Date:	4 Dec 79				4 Apr 80				15 Apr 80			
Water Surface Elevation (Ft. NGVD):	383.5				385.0				390.1			
Estimated Discharge (cfs):	2,400				2,700				13,400			
	At Toe		40 Ft. From Toe		At Toe		40 Ft. From Toe		At Toe		40 Ft. From Toe	
Reach	Depth (ft)	Mean Velocity (fps)	Depth (ft)	Mean Velocity (fps)	Depth (ft)	Mean Velocity (fps)	Depth (ft)	Mean Velocity (fps)	Depth (ft)	Mean Velocity (fps)	Depth (ft)	Mean Velocity (fps)
1	1.5	0.39	12.8	0.76	3.8	0.53	12.6	0.90	9.5	1.95	19.5	2.90
2	1.2	0.25	11.0	1.04	2.5	0.55	13.2	1.24	6.3	1.99	15.1	3.32
3	1.4	0.39	6.5	1.12	2.5	0.46	7.6	1.14	6.0	1.50	13.9	2.64
4	1.8	0.34	10.4	1.36	1.6	0.38	11.0	1.60	6.3	1.30	16.1	2.68
5	1.2	0.18	11.5	1.40	2.5	1.35	12.5	1.38	11.5	2.32	17.2	2.92

CONNECTICUT RIVER
HAVERHILL DEMONSTRATION SITE
VELOCITY MEASUREMENTS

CONNECTICUT RIVER AT NORTHFIELD, MASSACHUSETTS

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

CONNECTICUT RIVER AT NORTHFIELD, MASSACHUSETTS
DEMONSTRATION PROJECT PERFORMANCE REPORT

I. INTRODUCTION

1. Project Name and Location. Northfield Demonstration Site, Connecticut River, Northfield, Massachusetts. Location map shown on Plate 1.

2. Authority. Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251.

3. Purpose and Scope. This report describes a demonstration project constructed by the New England Division to experiment with innovative techniques of streambank erosion control. It presents a description of the bank erosion problem and types of protection used. At the time of this writing construction of the project was just completed, and there has been no experience on which to base any performance evaluation.

4. Problem Resume. A 2000-foot reach of the left (east) bank of the Connecticut River just downstream from the Route 10 highway bridge is actively eroding. The bank varies from 20 to 25 feet in height above its toe and is eroding at the rate of between 1 and 3 feet per year. The erosion site is located within the Turners Falls Dam hydropower pool and is subject to widely fluctuating water surface levels due to both upstream and downstream hydropower operations on the river. Annual spring high water inundates the lower bank and the whole bank is inundated by unusually high spring runoff or extreme flood flows. Erosion conditions are typical of those caused by streamflow along a steep bank comprised of alluvial soils. Pool fluctuations, seepage and boat waves play lesser roles in the overall erosion process at the site. The land being lost is fertile farmland of the mid-Connecticut River Basin floodplain.

II. HISTORICAL DESCRIPTION

5. Stream.

a. Topography. The project site lies in the central portion of the Connecticut River Basin, the largest in New England. Draining in a southerly direction with its source in northern New Hampshire and mouth at Long Island Sound in Saybrook, Connecticut, the Connecticut River extends more than 400 miles. The valley of the Connecticut River in its northern reaches where it forms the border between northen Vermont and New Hampshire is bounded on the west by the Green Mountains and east by the White Mountains, with mountain peak elevations of over 4000 feet NGVD being quite common. In this reach the valley floor is relatively narrow and of gentle terrain. Proceeding downstream toward the project site (approx. river mile 133) the valley floor widens with wide and extensive flood plains located in various reaches along the main stem. During major floods these areas act as large detention reservoirs which significantly reduce peak discharges at the project site. The lower mountain peaks (generally not over 2000 feet NGVD) of the southern Green Mountains of Vermont and Monadnock range of New Hampshire form the valley wall in the river reach just upstream from the project site. The normal stream gradient at the Northfield site is about 0.1 foot per mile.

b. Geology. The geology of the Connecticut River Basin can be subdivided into two distinct periods: prior to and following continental glaciation. Preglacial history of the Connecticut River is quite diverse. Bedrock of the area consists of heavily folded and faulted metamorphic and igneous rocks. The metamorphic rocks include phyllites, schists, and gneisses. The igneous bodies are granite, granodiorite, and quartz monzanite with occasional intrusions of volcanic materials. The trends of major structural features in Vermont and New Hampshire are in a north-northeasterly direction. This coincides with the Connecticut River which probably follows an ancient drainage way.

Preglacial geology indicates extensive periods of erosion associated with the uplift of the Appalachian Mountains near the close of the Paleozoic Era, and with other periods when the land was emergent. It is assumed that the present topography was well established prior to continental glaciation, including a well developed soil layer with superimposed streams including their meandering patterns.

Massive continental glaciation wore the topography into the currently existing subdued forms. Highlands were rounded on the upper side facing the glacier and steepened on the lower side away from the glacier. Stream valleys were eroded and smoothed, sometimes into the classic V-shaped glacial valleys.

The retreating ice redeposited morainal materials over the entire surface of the area. Stagnant ice blocks and frontal moraines created lakes that became sites of further deposition. While the lakes were in existence, material was deposited as sandy and gravelly terraces consisting of deep, well drained alluvial soils developing in medium textured sediments, derived mainly from schist, gneiss, granite, slate and phyllite. The type of alluvial material forming the flood plains adjacent to the Connecticut River comprise the Hadley soils as classified by the US Department of Agriculture, Soil Conservation Service, and are water-laid deposits composed mostly of silty, fine sands and nonplastic fine, sandy silts. Soil core samples were collected and analyzed. A bore hole log of the alluvial deposits is given on Plate 2.

c. Locality, Development and Occupation. The Northfield, Massachusetts site is located in the valley of the mid-Connecticut River Basin, noted for its rich alluvial soil which provides the foundation for one of the most productive farming areas in New England. Crops produced in the region include corn, tobacco, hay and assorted vegetables. The erosion site borders a large field used primarily for corn.

Vegetation in the areas not in agriculture is primarily woodland, including red and silver maple, elm, willow, cherry, poplar and alder. In the valley region, woodland is usually found on steep slopes and along the river. Some timber harvesting is done for lumber and firewood.

Northfield is a small agricultural, residential, and year-round resort community. Most of the labor force is engaged in construction, manufacturing, and the service industry. The population of Northfield (2,600 in 1970) has shown a slight steady increase since 1950. The town is served by 2 railroads and 2 major State roads, Routes 10 and 163.

d. Hydrologic Characteristics.

(1) Climatology. The relatively high elevations of the Green Mountains of Vermont and the Berkshire Mountains of Massachusetts influence the temperature, precipitation and snow cover of the central Connecticut River Basin which lies in the path of the prevailing westerlies and air masses moving predominantly from the interior of North America. Generally west to southwest air flow brings the hot dry weather which is responsible for occasional summer droughts. In the winter months, high pressure weather systems from Canada bring frigid air into the basin. Precipitation is moderate to heavy and well distributed throughout the year. The annual mean temperature is about 45°F.

Three general types of storms produce precipitation over the basin: continental, coastal, and thunderstorms. Continental storms originate over the western and central portion of the United States and move generally in an easterly or northeasterly direction.

Tropical hurricanes, the most severe of the coastal storms originate in the South Atlantic or Caribbean Sea. They usually move in a westerly direction then northerly and may be deflected by high pressure zones to New England. Hurricanes have occurred in the summer and fall months. Extratropical storms generally originate or intensify near the middle Atlantic States, travel northward along the coastline and generally occur in autumn, winter and spring.

The third type of storm is the thunderstorm which can be produced by local convective activity during the warm humid days of the summer months or be associated with a frontal system moving across the basin.

The average annual precipitation ranges from 43 inches in the main river valley to about 50 inches in the higher Berkshire and Green Mountains. Precipitation in the central portion of the basin during the winter months is practically all in the form of snow. The average snowfall ranges from 50 inches in the valley to 70 inches in the mountains.

(2) Streamflow. Flow conditions in the Connecticut River in the area of concern are best represented by the records of the U.S. Geological Survey gage at Turners Falls Dam (D.A. = 7163 square miles) located at river mile 122.2 about 11 miles downstream from the Northfield site. About 50 percent of the 23-inch annual runoff occurs during the months of March, April and May. During this period combined snowmelt and rainfall create an especially great chance of flooding. The average annual flow at the gage is 11,890 cfs for the period of record (1915 to present). Average summertime (July-October) flow rate is 5,700 cfs and the mean spring flow rate (April-May) is about 31,500 cfs. The average annual peak discharge has been 71,500 cfs since 1961, the year of final construction of all major upstream storage reservoirs. A peak discharge of 210,000 cfs was experienced in the great rainfall-snowmelt flood of March 1936. The recurrence interval of this peak flow rate is estimated to be slightly more than 100 years. Operation of the system of 9 flood control reservoirs, constructed by the New England Division on upstream tributaries since 1936, would cause this flow rate to be a more rare event today. Minimum flows at the gage approach 0 cfs during periods of "nongeneration" at Turners Falls Dam. A minimum daily flow rate of 99 cfs was recorded in October 1944 at the USGS gage on the Connecticut River at Vernon, Vermont (D.A. = 6266 square miles) located about 10 miles upstream from the Northfield site.

e. Channel Conditions. Under normal to moderate flow conditions the Connecticut River passes through the well defined channel it has cut through the valley floor alluvium (Plate 1 and Photo 1). The river takes a meandering course and, typically, is continually eroding its banks which are generally steep and sloughing and consist mainly of silty sands and sandy silts. Overtopping of the riverbank occurs at a flow rate of about 90,000 cfs, or on the average only every 10 or so years.

Water surface levels under normal conditions vary widely on a daily and weekly basis in the Turners Falls Pool. This reach of the Connecticut River is bounded by Turners Falls Dam on the downstream end and Vernon Dam on the upstream end. The flow regime is affected by the operation of both of these hydropower projects and by the Northfield Mountain Pump Storage Facility located mid-reach in the Turners Falls Pool and which uses the pool for both forebay (pump cycle) and afterbay (generation) during its operation. Water levels at Turners Falls Dam fluctuate about 3.5 feet daily, on the average and range between elevations 175 and 185 NGVD, the operational zone, on a weekly basis. Plate 5 shows a graph of typical weekly pool fluctuations.

f. Environmental Considerations. The bank stabilization project is expected to result in a net improvement in wildlife habitat and water quality. The riverbank origianlly was a severely eroded cliff of sloughing vegetation, mostly grass and shrubs, with a few large trees at the top of the bank. The stabilized slope, revegetated above toe protection structures with unmown grass, legumes, vines and shrubs, will provide an improved habitat corridor along the river. Bank stabilization and toe protection will also reduce siltation and localized turbidity in the Connecticut River. Removal of scattered trees along the top of the bank, and replacement with uniform vegetation and manmade structures on the lower slope will give the project an unnatural character in contrast to adjacent riverbanks. This effect will be minimized in the long term by natural revegetation with a wider variety of native plant species.

6. Demonstration Site - Test Reach.

a. Hydrologic Characteristics. The hydrologic aspects of the test site are as previously described in Section 5d. Hydrographs of average monthly and average daily discharges measured at Turners Falls Dam are shown on Plates 3 and 4, respectively. Ice usually forms along the shore around late December (actual time of occurrence varies from year to year depending upon coldness of air temperature) and often forms an entire cover on the river. The ice usually breaks up during the spring snowmelt runoff period in April.

b. Hydraulic Characteristics. As previously discussed in Paragraph

5e, the demonstration site is situated mid-reach in the Turners Falls Dam pool and is subject to regular daily and weekly water level and flow fluctuations (Plate 5) due to both downstream and upstream hydropower operations and to operation of a pump, storage facility located on the left bank a few miles downstream. An approximate stage vs. discharge rating curve for the Connecticut River at the Northfield site is given on Plate 6. Stream velocities along the bank were observed to be 2 to 3 fps during a discharge of 50,000 cfs. Under high floodflow conditions, hydraulic control of this reach of river shifts from the backwater effect of Turners Falls Dam to the natural control at the valley constriction located near the French King Bridge (river mile 126.3) and the water surface slope increases from the normal 0.1 foot per mile to about 0.3 foot per mile. Velocities near the bank under these flow conditons are not known.

Wind generated waves are a relatively insignificant cause of bank erosion at the demonstration site due to extremely limited fetch. Also, boat generated waves play a minor role compared to other causative hydraulic factors as there is no commercial navigation and only a small amount of recreational boating traffic.

c. Riverbank Description.

(1) Bank Materials. Materials composing the banks and valley floor of the Connecticut River are classified as silty fine sands and fine, sandy silt. Alluvial deposits in the vicinity of Northfield, Massachusetts are comprised mainly of the Hadley soils. Analysis of the boring log for the project site indicates a 1 to 2 foot layer of clayey sandy silt (ML) overlying a deep stratum of silty fine sand (SM). Soil classification is given on the boring log on Plate 2.

(2) Description of Vegetation. Vegetation in the test reach was primarily a narrow band of grass, shrubs and a few large trees between the river and a large agricultural field. The trees were primarily elm, red maple and cherry species. Shrubs included alder, dogwood, wild rose and other brambles, and sumac. Grasses and forbes were a typical mix of native and introduced species usually associated with agricultural areas in the Northeast.

(3) Erosion Conditions. Thirteen sites along the banks of the Connecticut River in the pool behind Turners Falls Dam (river miles 122 to 142) are eroding. Although rates of erosion have not been determined at the other locations, the Northfield site is eroding at about 1 to 3 feet per year. Most of the sites are subject to the sloughing type of erosion; a lesser number are subject to mass wasting, headcutting and shallow washing. The principal cause is shear stress associated with high streamflow. Other causes such as pool fluctuation, boat waves, overbank drainage, and seepage play lesser roles in the overall erosion process. Erosion prior to construction of the demonstration project is shown in Photo 1.

Northeast Utilities Company (NU) made extensive efforts to stabilize major segments of the banks of Turners Falls Pool, mainly through the use of tree clearing and hydroseeding during the mid-1970's. Some riprap revetment was also used. At the demonstration site the trees had been cleared and the raw bank had been hydroseeded. A complete description of the stabilization work by NU is given in Section 32 Program Inspection Report 6, by Malcolm P. Keown, Hydraulics Laboratory, U.S. Army Waterways Experiment Station, May 1979.

III. DESIGN AND CONSTRUCTION

7. General. Three different and somewhat innovative methods of streambank protection were used in the Northfield demonstration project. These included three types of revetment - precast cellular concrete block mattress, used auto tire wall and used auto tire mattress. All three revetment panels included vegetative protection on the upper bank. The arrangement of the various test panels is shown on Plate 7.

8. Basis for Design.

a. Lower Bank Protection. The primary goal in selecting the types of protection to be utilized was to gain experience with new and innovative methods of streambank erosion control. Precast cellular concrete block mattress was selected because of its commercial availability and

and the New England Division's desire to gain field experience with it. Used auto tire wall and mattress were selected on the basis that they are readily available materials and on the premise that they would require relatively simple construction techniques that local government agencies and private land owners could employ.

b. Upper Bank Protection. Upper bank protection was provided by a series of test areas of various mixes of grasses, legumes, vines and shrubs. In general, vegetation was used as an alternative to more expensive structural measures in the portion of the bank above normal high water line, and also as a more natural appearing bank cover in the project's rural setting. Selection of plant species was based on knowledge of suitable native and adapted species types commercially available in the region. Additional technical assistance was provided by the Soil Conservation Service (SCS), U.S. Department of Agriculture. Two methods of mulching were also selected for comparision: hay with plastic netting, and tobacco netting with wood fiber mulch. Grasses were selected to provide a thick vegetative mat that protects the soil surface from the erosive effects of rainfall and high stage river flows, and to buffer the impact of floating debris, induce minor silt deposition, and reinforce and stabilize the soil surface through extensive fine textured roots. Shrubs and vines, planted as container grown, healthy, young plants provide less rapid soil protection but better wildlife cover and food potential.

Plates 7 and 8 outline the plant species used and their location in the project. In general, the experimental grass mixes were chosen on the basis of rapid establishment, suitability for growth with little or no maintenance, and adaptability to periodic inundation. Legumes were added to some mixes for supplemental nitrogen. Shrub species were chosen for wildlife value and adaptability to periodic inundation. Vines were chosen for their hardiness, woody perennial growth and ability to provide rapid low cover.

9. Construction Details. The total project length is about 2000 feet. Three techniques of bank protection, described below and shown on Plates 7 and 9, were installed in reaches varying in length from 600 to 750 feet

each along the bank.

a. Reach 1. A precast cellular concrete block mattress (Nicolon Class 64 Gobimat) was constructed along the lower portion of the bank for a length of 600 feet (Photo 4). The mattress was formed by placing 4-foot wide by 20-foot long cellular concrete block mats at right angles to the river on a 2H to 1V graded slope above the normal low water line and on the existing slope below the normal low water line. The cellular concrete mats were plant assembled prior to delivery and placement, (Photo 2) and consisted of a series of concrete blocks, each measuring 8 inches wide by 8 inches long by 5 inches high and weighing about 15 pounds, glued to a plastic filter/carrier fabric. Voids in the cellular concrete mattress were filled with pea stone (Photo 3) and the mattress was anchored to the bank using No. 6 reinforcing steel rods spaced at 4 foot intervals along the top of the mats. The upper bank was formed to a 2H to 1V slope and seeded.

b. Reaches 2 and 3. An 18-inch thick rock berm was placed along the toe of the bank from the normal low water line to a depth of about 5 feet. A wall consisting of used auto tires was constructed above the rock toe protection on a 1H to 1V slope and to height of 7 feet above the rock toe (Photo 7). The auto tire wall was assembled in layers with each layer of tires being banded together with stainless steel bands (Photo 5). The auto tires were filled with crushed stone (Photo 6) and anchored to the slope with No. 6 reinforcing steel rods at each tire in the top row. Filter fabric (Nicolon 70/20 - woven) was placed behind the tires along Reach 2 for a length of 350 feet. Reach 3, identical to Reach 2 in all other respects had no fabric. The upper bank of both reaches were formed to a slope of 2H to 1V and seeded.

c. Reaches 4 and 5. The final section consists of an underwater rock blanket below the normal low water line and an auto tire mattress consisting of two layers of tires banded together with stainless bands and placed on a 2H to 1V slope above the normal low water line. The used auto tires were filled with crushed stone. Filter fabric (Nicolon 70/20 - woven) was placed under the mattress for the 350-foot length of Reach 4. Reach 5, also 350 feet in length, was not provided with fabric. The mattresses were anchored to the slope with No. 6 reinforcing steel rods at each tire along the top. The upper bank was graded to a 2H to 1V slope and seeded.

10. Costs. Total cost and unit cost on a linear foot basis for each of the test reaches in the Northfield project are shown in the following table. These costs were developed from contractor bid items and do not include 6 and 7 percent markups for Corps of Engineers engineering and design, and supervision and administration, respectively.

Test Reach	Total Cost (Dollars)	Cost Per Linear Foot (Dollars)
1	119,700	200
2	54,500	145
3	41,000	109
4	62,150	178
5	48,900	163

Costs are based on 1980 prices. The final total contract cost for the project, which was completed in November 1981, was $411,634.

IV. PERFORMANCE OF PROTECTION

11. Monitoring Program. Due to the exhaustion of monitoring funds under the Section 32 program, no formal monitoring plan has been developed for the Northfield site. It is hoped that funds under some other authority will be made available to at least carry out a visual inspection program now that the project is completed. It is imperative to continue to observe this site in the future if any knowledge is to be gained regarding performance of the protective measures.

12. Evaluation of Protection Performance. As of this writing, construction of the demonstration project was just completed and thus no evaluation of performance of the erosion control measures is possible.

13. Rehabilitation. None required to date.

14. Conclusions. Since construction was not completed until November

1981, conclusions regarding performance of protective measures cannot be made at this time, nor are any expected to be reached in the future without the availability of funds to monitor performance.

PHOTO 1
FLOW FROM LEFT TO RIGHT
NOVEMBER 1976

NORTHFIELD PROJECT
PRE-CONSTRUCTION

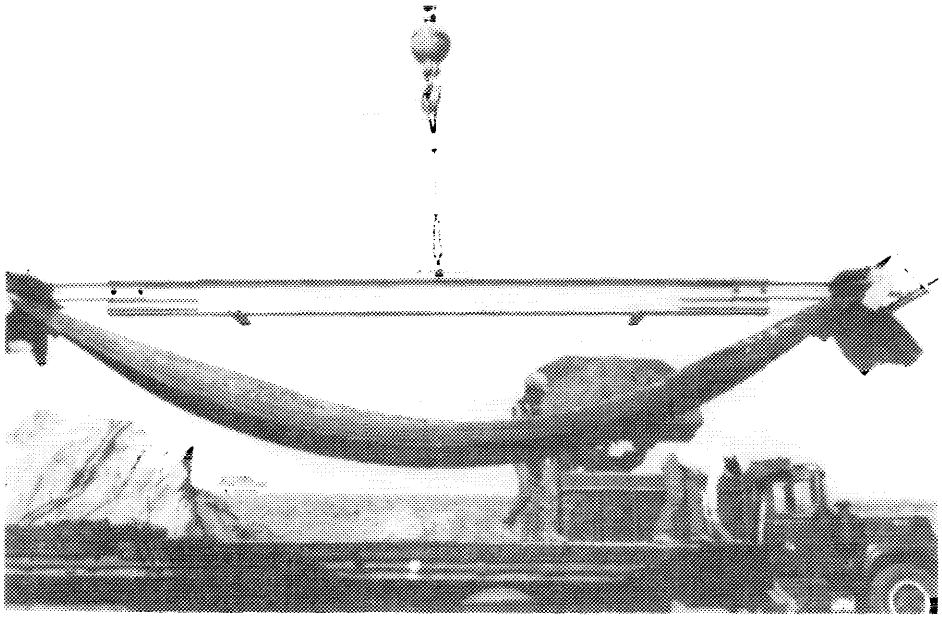


PHOTO 2
GOBIMAT
OCTOBER 1980

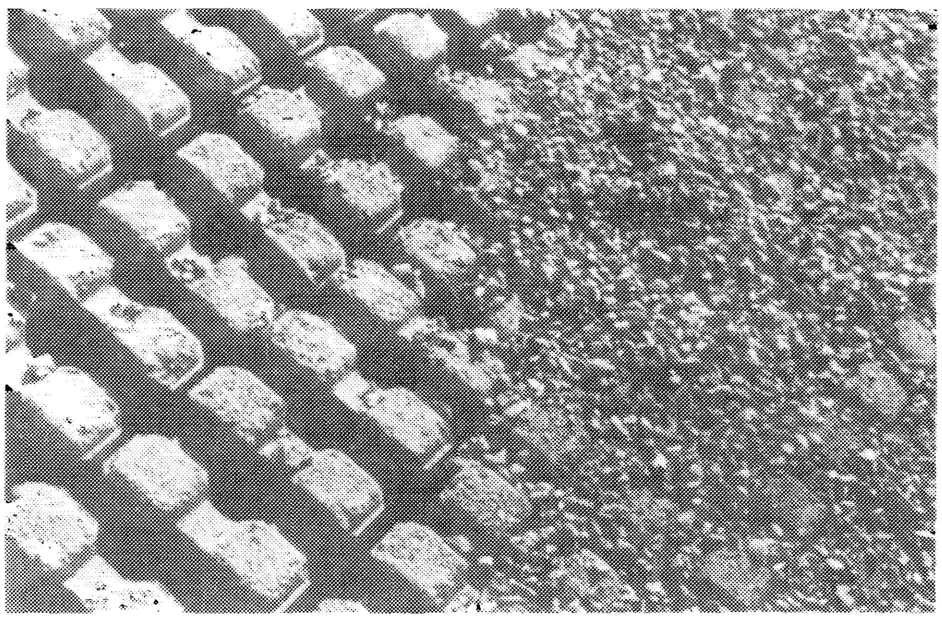


PHOTO 3
GOBIMAT CLOSE-UP
OCTOBER 1980

NORTHFIELD PROJECT
DURING CONSTRUCTION

PHOTOS 2 AND 3

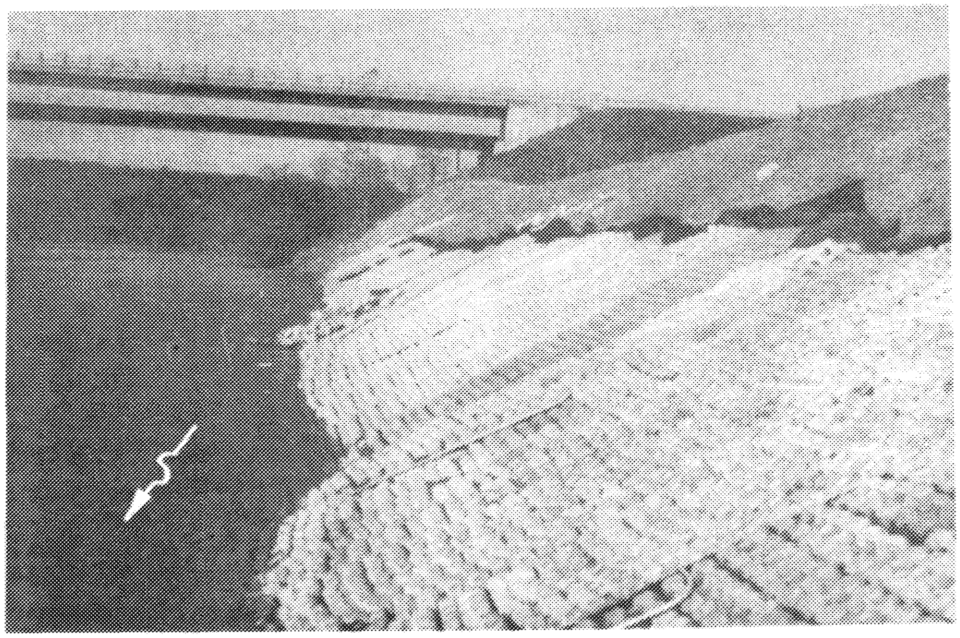


PHOTO 4
GOBIMAT
OCTOBER 1980

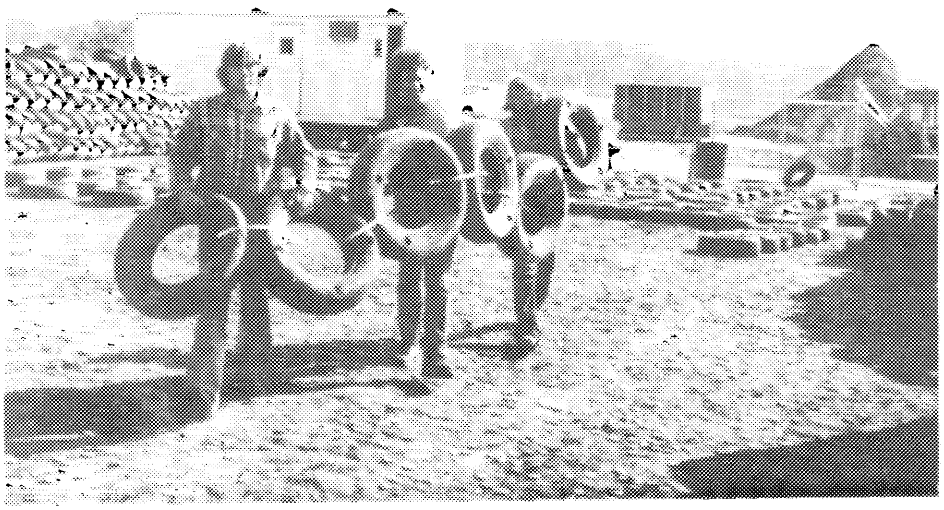


PHOTO 5
TIRE PREPARATION
OCTOBER 1980

NORTHFIELD PROJECT
DURING CONSTRUCTION

PHOTOS 4 AND 5

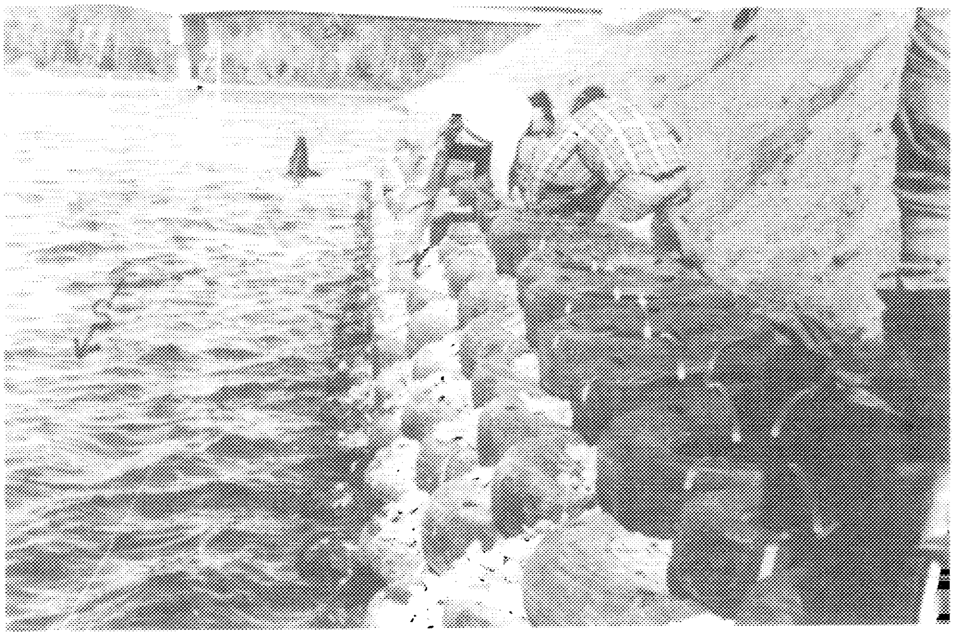
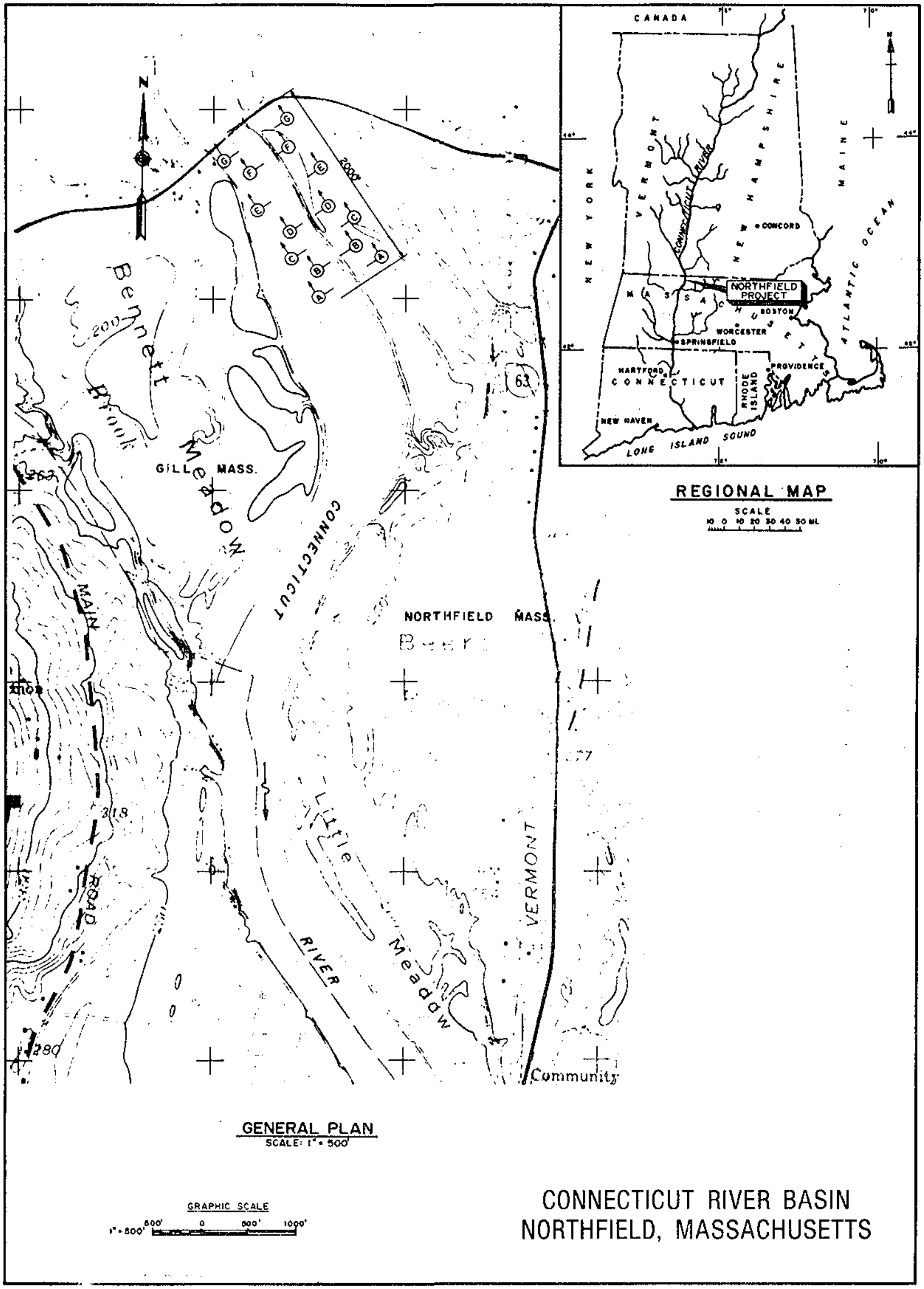


PHOTO 6
INSTALLING TIRE BULKHEAD
OCTOBER 1980

PHOTO 7
FINISHED TIRE BULKHEAD
OCTOBER 1980

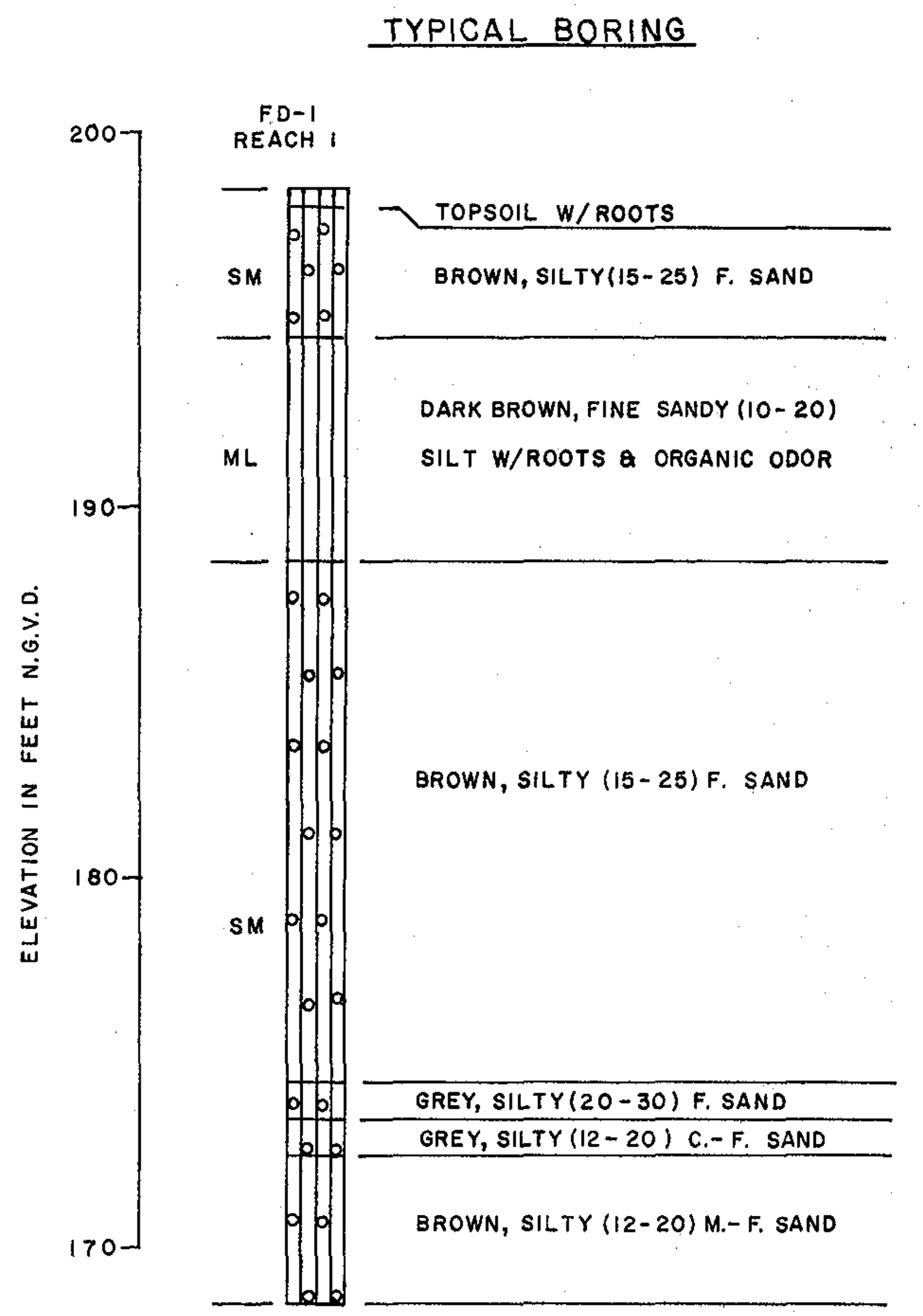
NORTHFIELD PROJECT
DURING CONSTRUCTION

PHOTOS 6 AND 7



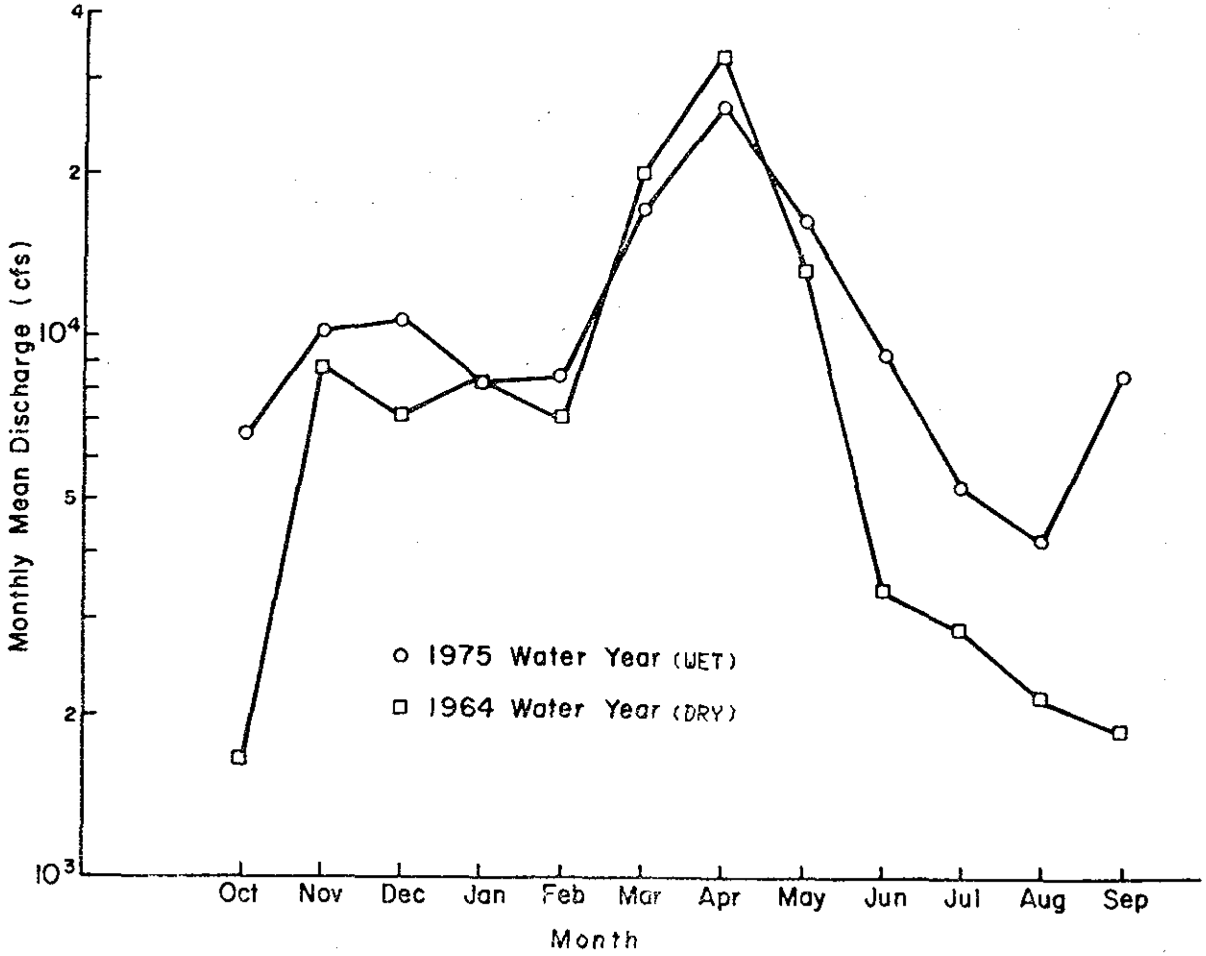
CONNECTICUT RIVER BASIN
NORTHFIELD, MASSACHUSETTS

PLATE 1



GEOLOGIC SECTION

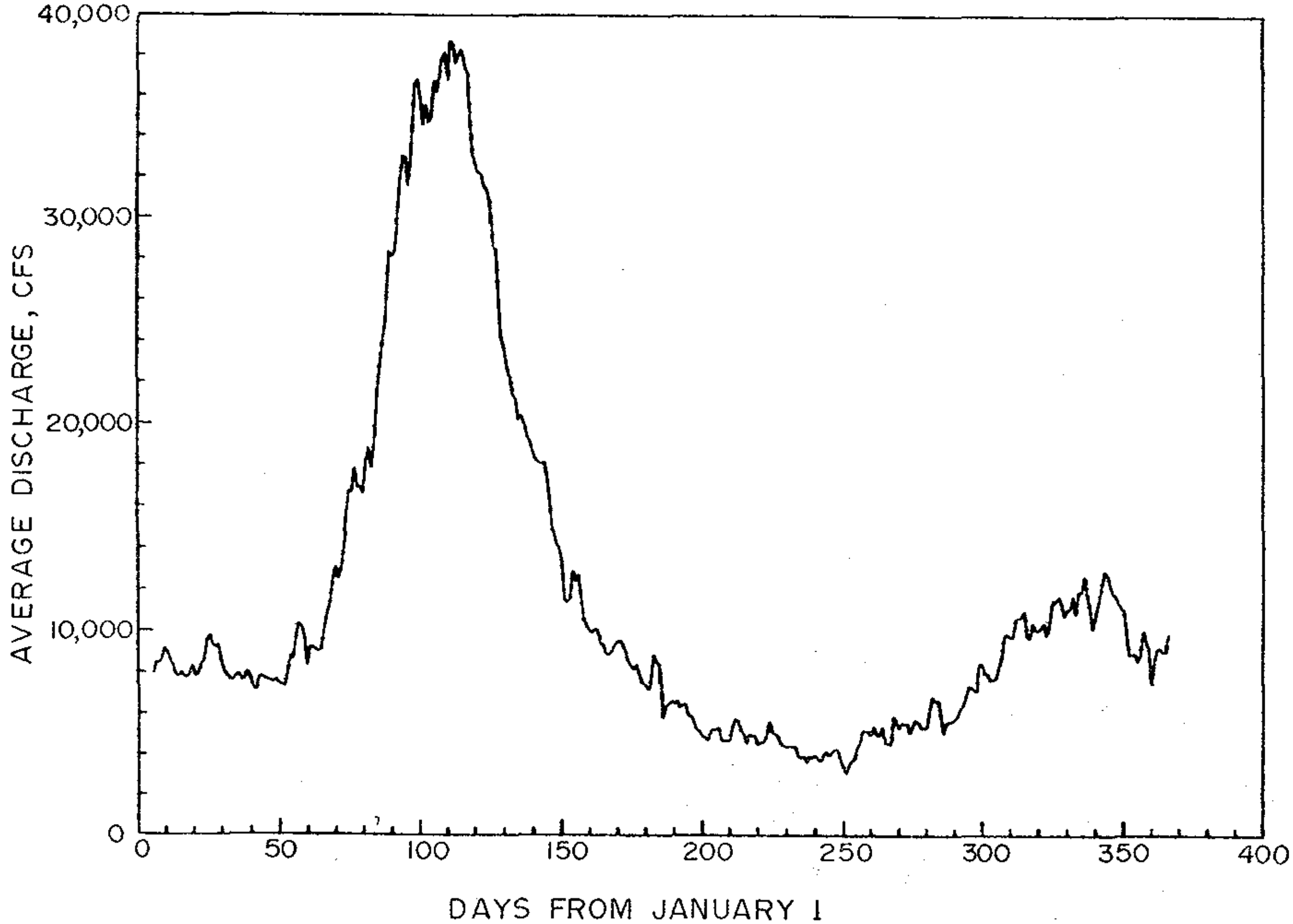
PLATE 2



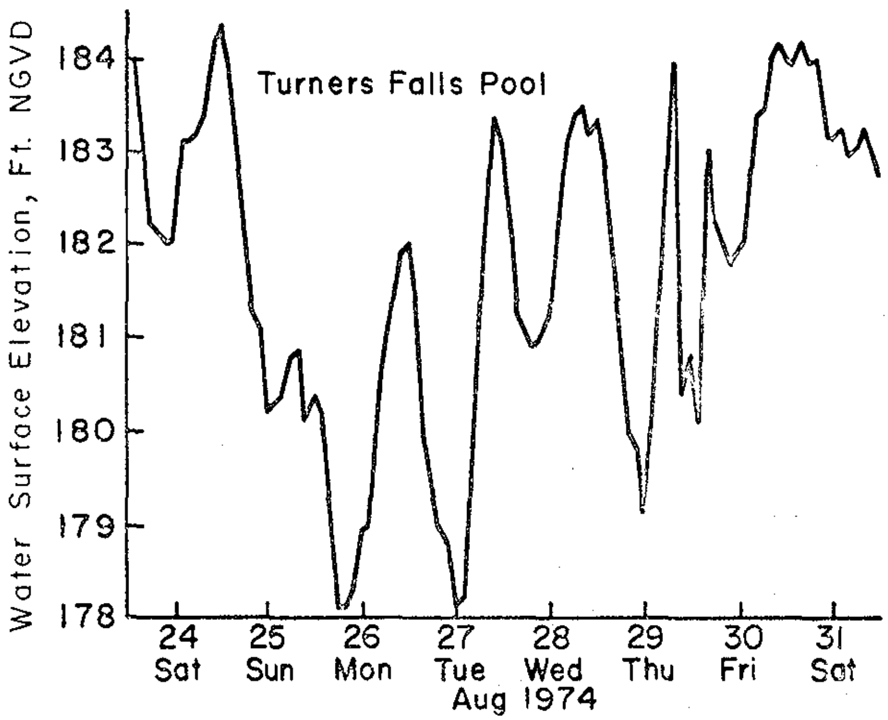
AVERAGE MONTHLY DISCHARGE
AT TURNERS FALLS DAM

G-55-19

PLATE 3

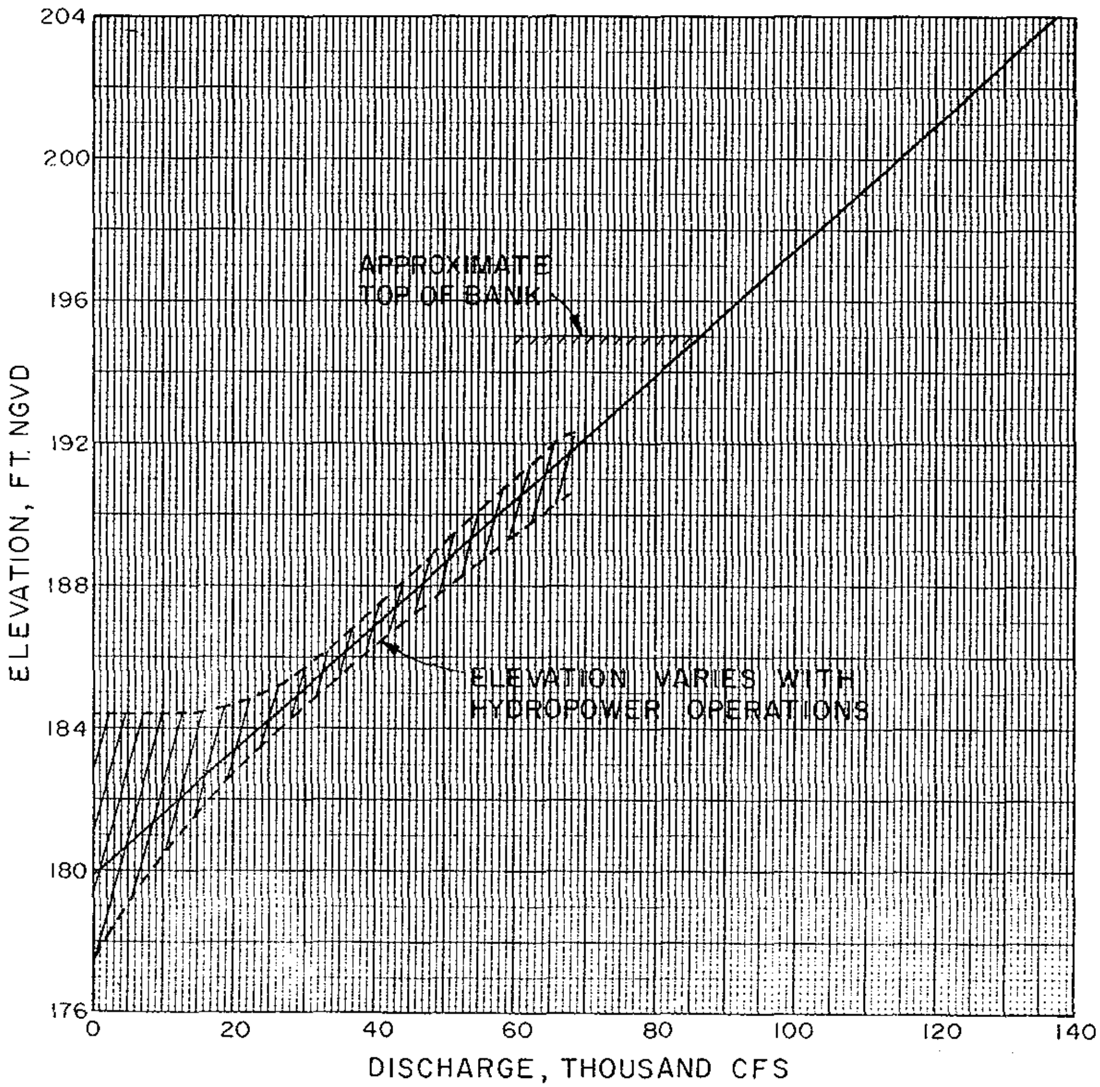


CONNECTICUT RIVER
TURNERS FALLS DAM
AVERAGE ANNUAL HYDROGRAPH

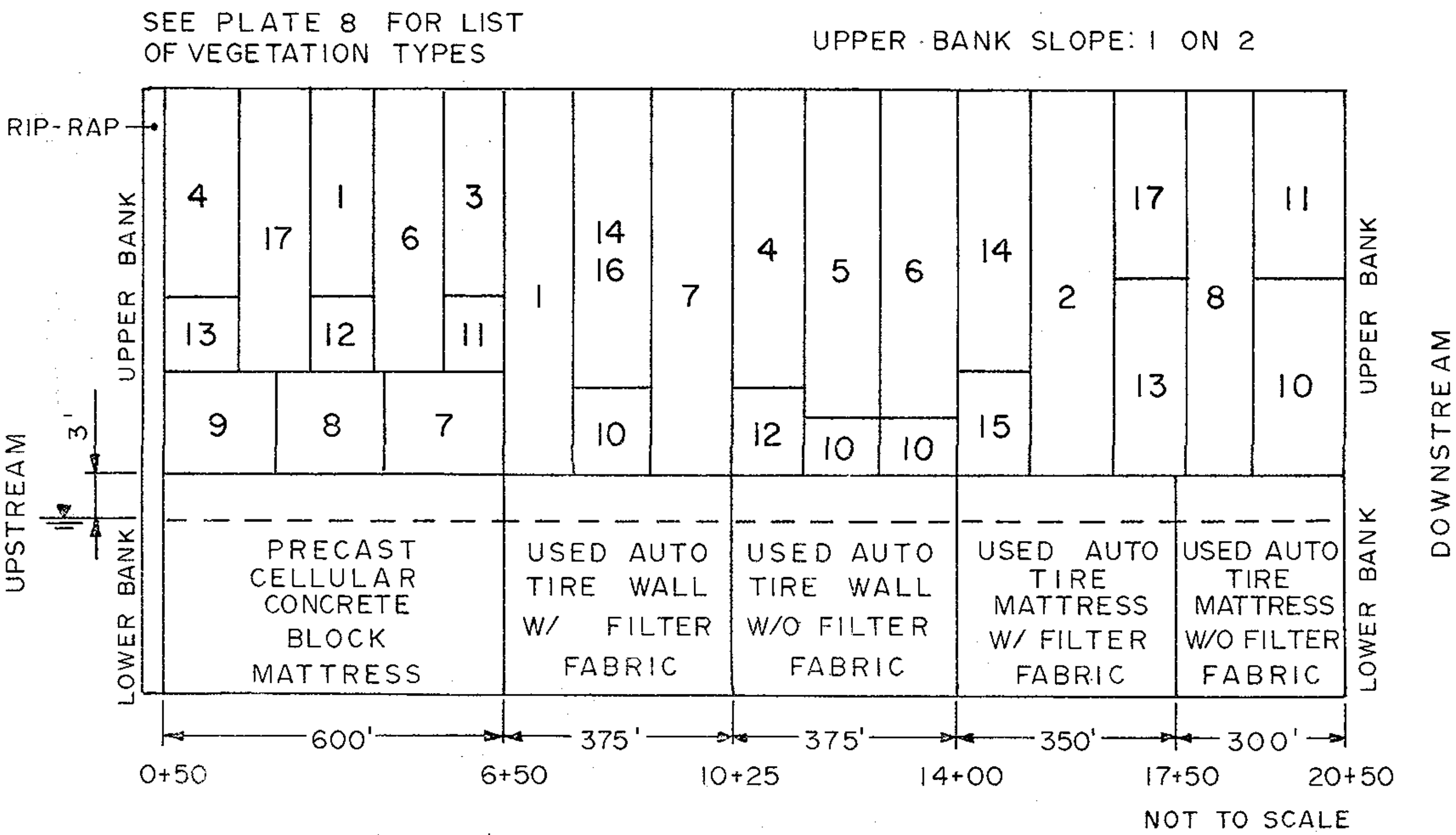


TURNERS FALLS
POOL FLUCTUATIONS

PLATE 5



APPROXIMATE STAGE
DISCHARGE RELATIONSHIP
NORTHFIELD DEMONSTRATION SITE



CONNECTICUT RIVER
NORTHFIELD, MASSACHUSETTS
PROTECTIVE MEASURES

G-55-23

PLATE 7

SEED MIXTURES

1 REED CANARYGRASS
CREEPING RED FESCUE
REDTOP

2 REED CANARYGRASS
KENTUCKY 31 FESCUE
BIRDSFOOT TREFOIL

3 CROWNVETCH
KENTUCKY 31 FESCUE
CREEPING RED FESCUE

4 FLAT PEA
KENTUCKY 31 FESCUE
CREEPING RED FESCUE

5 CROWNVETCH
FLAT PEA
KENTUCKY 31 FESCUE

6 BIRDSFOOT TREFOIL
CREEPING RED FESCUE

7 KENTUCKY 31 FESCUE
CREEPING RED FESCUE
REED CANARYGRASS
REDTOP

8 KENTUCKY 31 FESCUE
CREEPING RED RESCUE
REDTOP

9 PERENNIAL RYEGRASS
REDTOP

SHRUBS AND VINES

10 PURPLE-OSIER WILLOW

11 SIBERIAN DOGWOOD

12 REDOSIER DOGWOOD

13 SUMMERSWEET

14 AMERICAN BITTERSWEET

15 VIRGINIA CREEPER

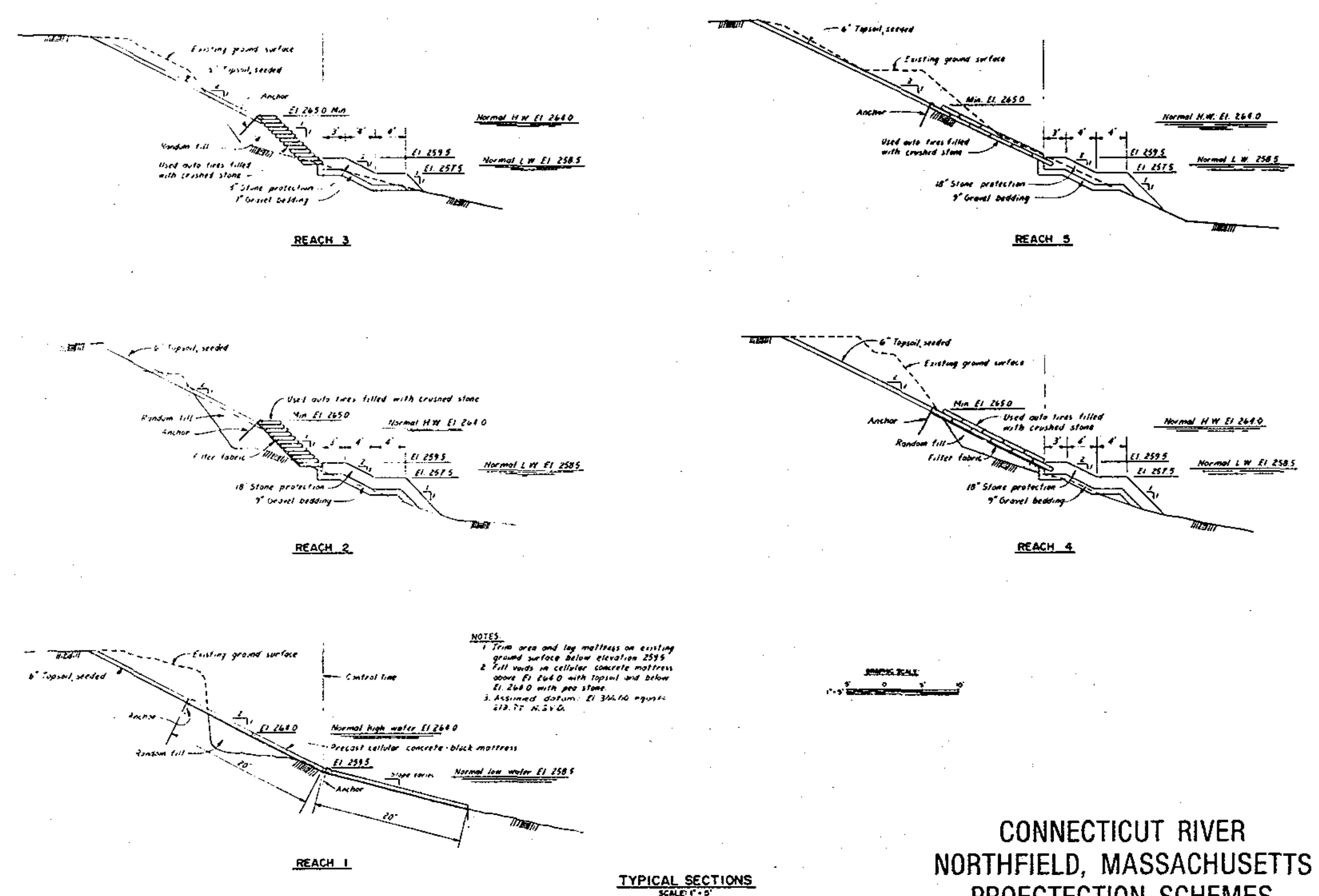
16 HALL'S HONEYSUCKLE

17 SWEETFERN

NOTE: NUMBERS ARE KEYED TO PANELS ON PLATE 7

NORTHFIELD DEMONSTRATION PROJECT
UPPER BANK VEGETATION

PLATE 8



CONNECTICUT RIVER
NORTHFIELD, MASSACHUSETTS
PROECTECTION SCHEMES

G-55-25

PLATE 9

CONNECTICUT RIVER

HANOVER, NEW HAMPSHIRE

Streambank Erosion Control Evaluation and Demonstration Act of 1974
Section 32 Program - Work Unit 2

EVALUATION OF EXISTING BANK PROTECTION WORKS

(1) Location

Stream Connecticut River River Mile 219.2-221.2 Side Left

Local Vicinity Hanover, NH Lat N43°42.5 Long W72°17.5'

At/Nr City Hanover County Grafton State NH Cong Dist 2

CE Office Symbol NED Responsible Agency New England Power Company

Site Map Sources USGS Topographic Quadrangle for Hanover, VT-NH, 1959

Land Use Information Source Dartmouth College

(2) Hydrology at or Near Site

Stage Range 380 to 385 ft; Period of Record 1949 to 1980.

Discharge Range very small to 50,000 cfs; Velocity Range very small to 3-10 fps

Sediment Range ukn to - tpd; Period of Record 19 - to 19 -.

Bank-full Stage ukn ft; Flow ukn cfs; Average Recurrence Interval ukn yr

Bank-full Flow Velocity: Average ukn fps; Near Bank ukn fps

Comments Site located in pool behind Wilder Dam a "run of river" facility Site is subject to daily water-surface fluctuations of about 2 feet.

(3) Geology and Soil Properties

Bank (USCS) Sandy silt to silt med/fine sand Bed (USCS) Sandy silt to med/fine sand

Data Sources Corps of Engineers

Groundwater Bank Seepage None observed

Overbank Drainage None observed

Comments

(4) Construction of Protection

Need for Protection To prevent streambank erosion.

Erosion Causative Agents Steep slopes, velocity, pool and groundwater fluctuations, wave action, freeze-thaw, and ice action.

Protection Techniques Riprap revetment

General Design Riprap layer overlying gravel fill and sand bedding material.

Project Length 9,000 ft; Construction Cost $ * Mo/Yr Completed 1962*

* See attached Item 23-1 for above information.

(5) Maintenance

Experienced Flows (Stage, cfs, Date) 385 ft NGVD, 50,000 cfs, 1 July 1973

Repairs and Costs (Item, Cost, Data) None to date

Comments:

(6) Performance Observations and Summary

Monitoring Program Semiannual (spring and fall)

Documentation Sources Photographs and trip reports for each visit

Project Effect on Stream Regime Negligible

Project Effect on Environment Negligible

Successful Aspects Project generally good condition with no signs of erosion.

Unsuccessful Aspects Minor erosion of upper slope by surface runoff.

General Evaluation Toe protection in good condition. Upper bank not protected from surface runoff.

Recommendations Surface runoff should be controlled and vegetation established on slope.

(7) Additional Information, Comments, and Summary

Map No. 23. In more than 20 yrs that the revetment has been in place it has generally stood up well.

Attached Items:

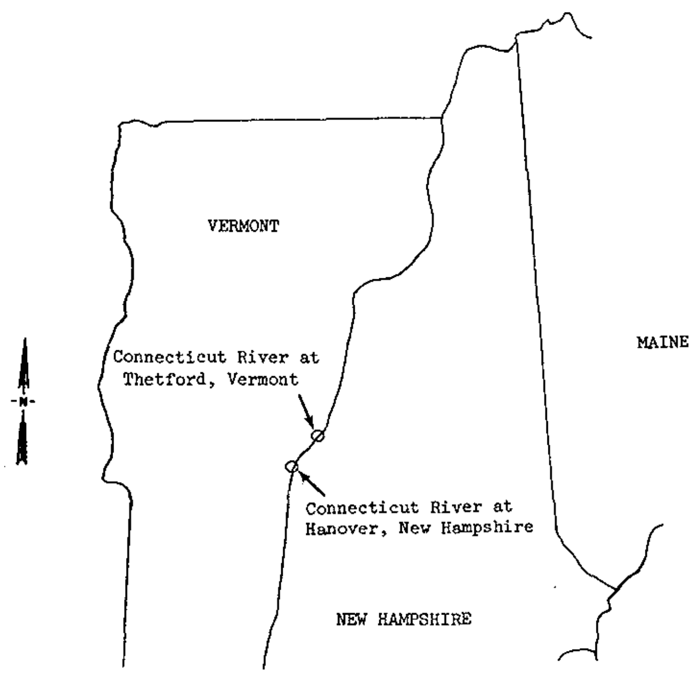
23-1 Project summary and location
23-2 Project vicinity map
23-3 Cross section and general view
23-4 Photographs immediately and 26 yrs after construction

Connecticut River

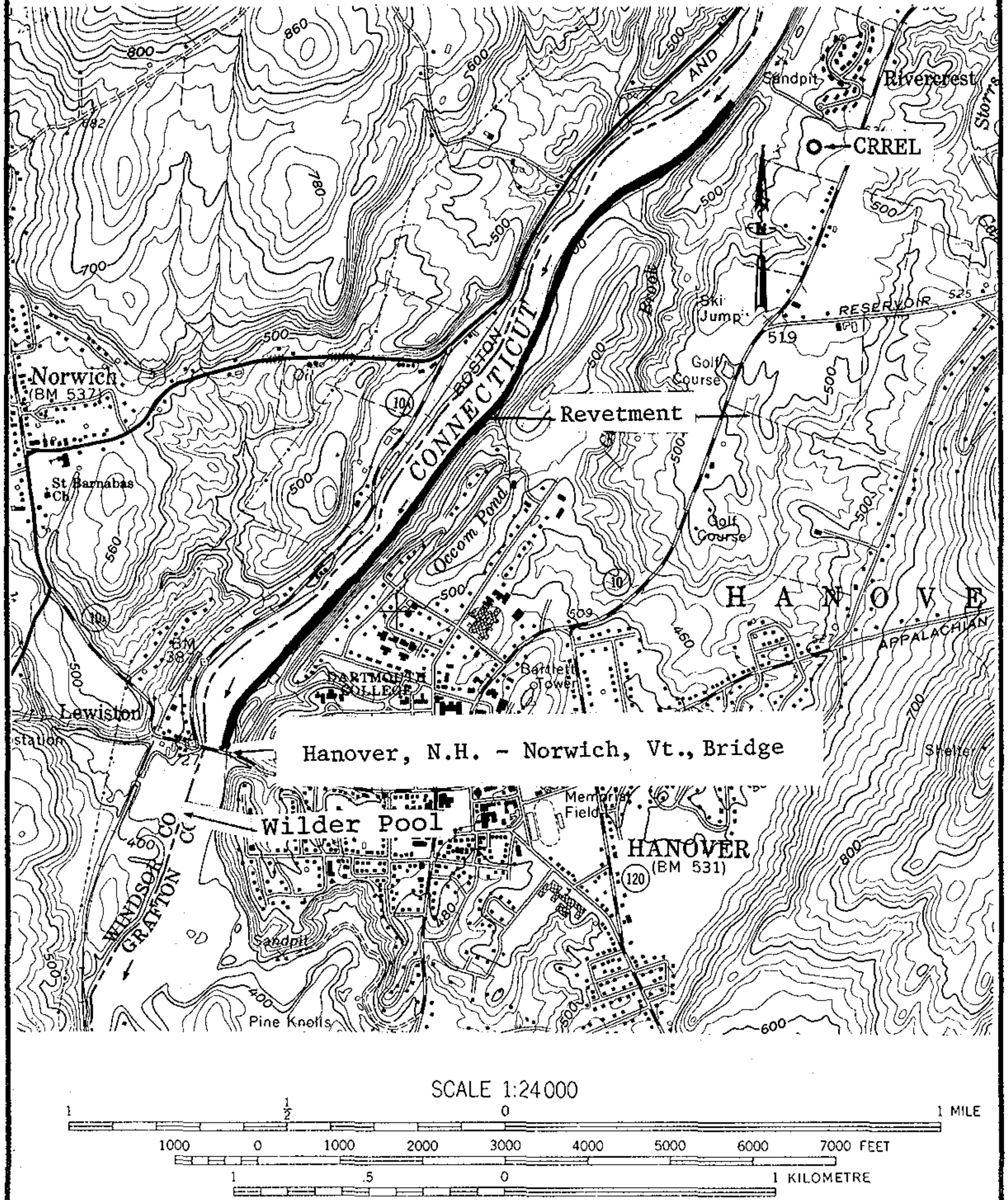
at Hanover, N.H.

Between 1950 and 1962, New England Power Co. (NEPCO) placed "run-of-the-blast" stone riprap along 9000 ft. of the left bank of the Connecticut River that fronts Dartmouth College. NEPCO followed no job specification except that it did not accept any stone having diameters larger than 12 in. The stone was placed from a barge. The site is subject to daily power pool fluctuations of approximately 2 ft. At the time of the 1978 and 1979 inspections, a stand of vegetation had become established, and the revetment was performing adequately. The NEPCO Engineering Department indicates that only minor failures have occurred and no major repairs have been necessary. There are a few small areas of erosion above the stone riprap where some large trees have become unstable and fallen taking part of the bank with them. These trees are above the elevation of any recently recorded flood levels.

*Construction	4800± ft.	$132,000	1953
Phased over several	2150	$24,800	1956
years	2150	$37,500	1962

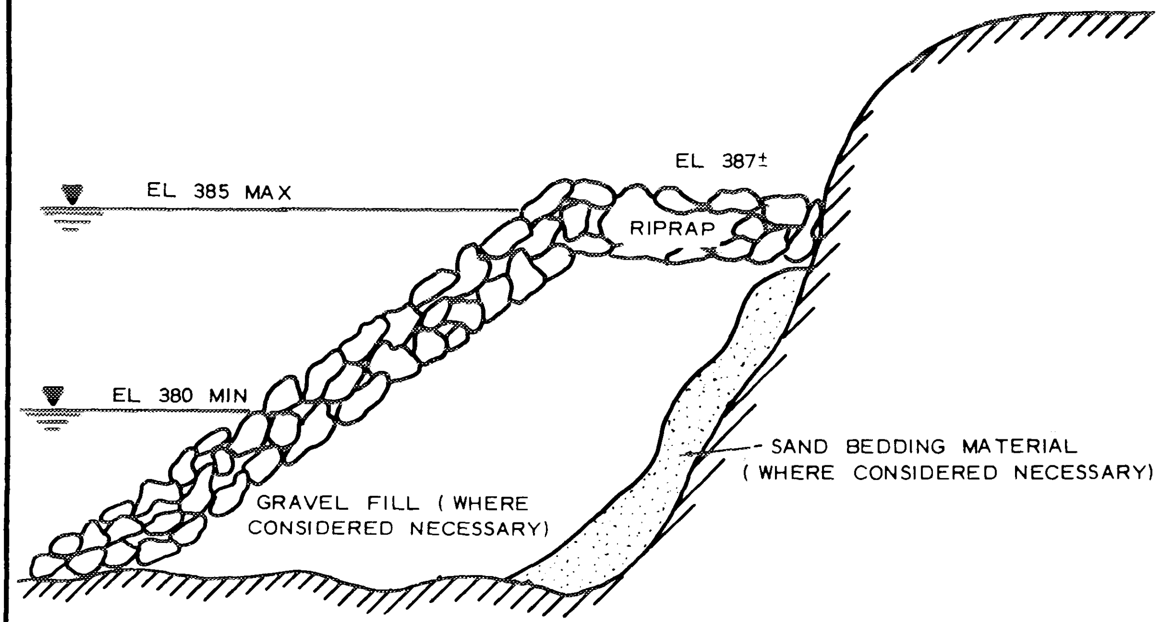


ITEM 23-1



CONNECTICUT RIVER AT HANOVER, N. H.
(*Source:* USGS 1:24,000 topographic quadrangle map for Hanover, Vt.-N. H., 1959)

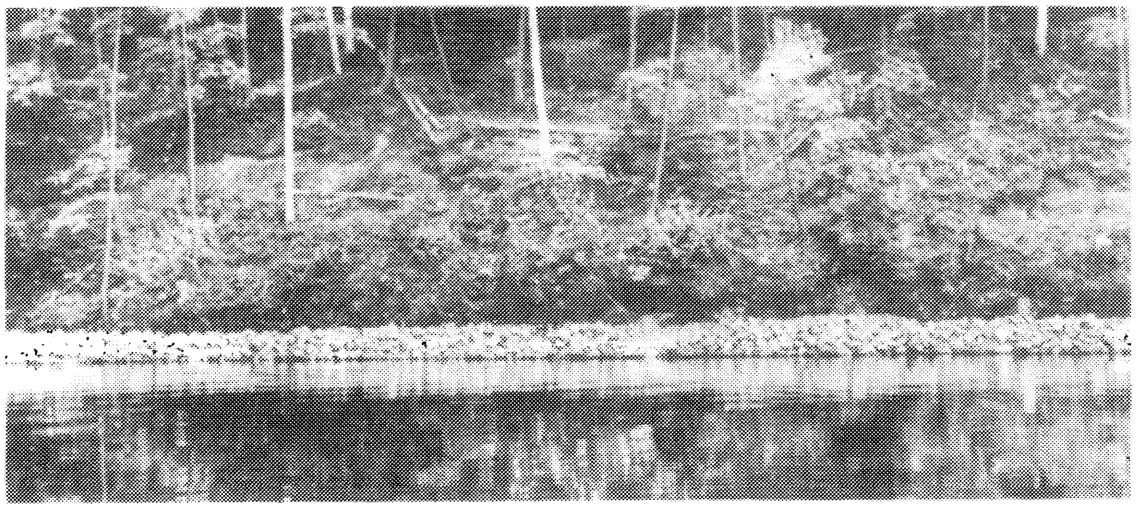
ITEM 23-2



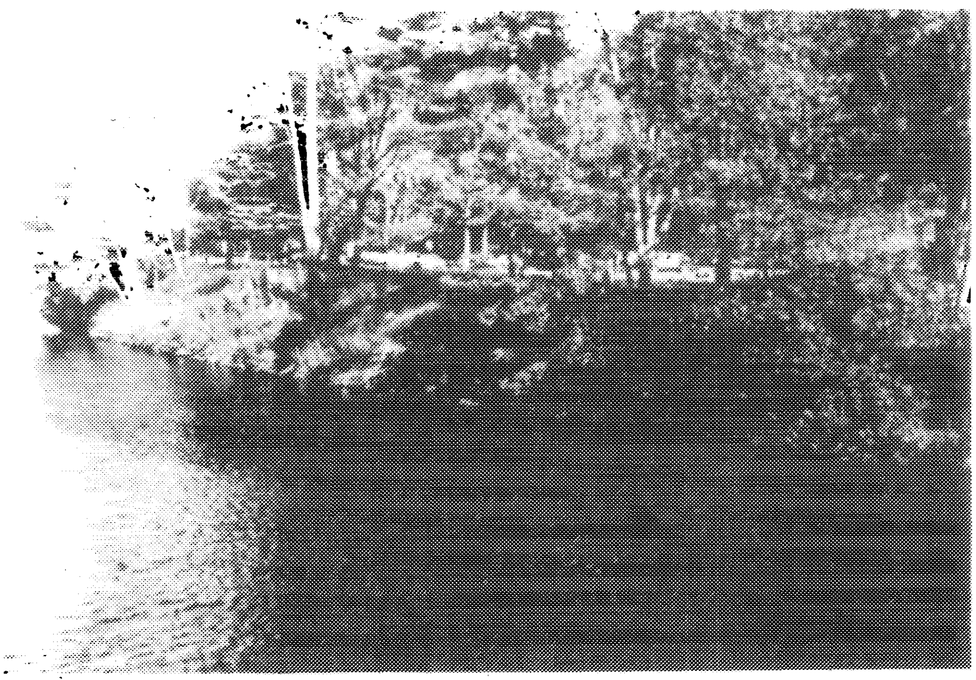
Cross-sectional plan of riprap revetment, Connecticut River at Hanover, N. H. (diagram furnished by New England Division)

View of sand bedding material, Connecticut River at Hanover, N. H. The revetment work was built as part of the Wilder Dam reconstruction project. The normal high water is now within 1 ft of the top of the revetment (photograph furnished by New England Power Company, 1954)

ITEM 23-3



View of in-place riprap, Connecticut River at Hanover, N. H. The revetment work was built as part of the Wilder Dam reconstruction project. The normal high water is now within 1 ft of the top of the revetment. Streamflow is to the right. (Photograph furnished by New England Power Service Co., 1954)



View of riprap 26 years after construction on Connecticut River at Hanover, N. H.

PHOTOGRAPHS IMMEDIATELY AND 26 YEARS AFTER CONSTRUCTION

ITEM 23-4

CONNECTICUT RIVER
THETFORD, VERMONT

Streambank Erosion Control Evaluation and Demonstration Act of 1974
Section 32 Program - Work Unit 2

EVALUATION OF EXISTING BANK PROTECTION WORKS

(1) Location

Stream Connecticut River River Mile apr 225 Side Right

Local Vicinity Thetford, VT Lat N43° 45' Long W72°13'

At/Nr City Thetford County Orange State VT Cong Dist at large

CE Office Symbol NED Responsible Agency Mr. Lyman Allan

Site Map Sources USGS Topographic quadrangle map for Mt. Cube, NH-VT, 1931

Land Use Information Sources Private home resident (Lyman Allan)

(2) Hydrology at or Near Site

Stage Range 380 to 386 ft; Period of Record 1949 to 1980.

Discharge Range v.small to 50,000 cfs; Velocity Range v.small to 3-10 fps

Sediment Range ukn to - tpd; Period of Record 19 - to 19 -.

Bank-full Stage ukn ft; Flow ukn cfs; Average Recurrence Interval ukn yr

Bank-full Flow Velocity: Average ukn fps; Near Bank ukn fps

Comments Site located in pool behind Wilder Dam a "run of river" hydro facility. Site is subject to daily water-surface fluctuations of about 2 feet.

(3) Geology and Soil Properties

Bank (USCS) Sandy silt to silty med/fine sand Bed (USCS) Sandy silt to med/fine sand

Data Sources Corps of Engineers

Groundwater Bank Seepage None observed

Overbank Drainage None observed

Comments

(4) Construction of Protection

Need for Protection To prevent streambank erosion

Erosion Causative Agents Steep slopes, river velocities, pool and groundwater fluctuations, wave action, frost and freeze-thaw action on cohesionless soil, ice action

Protection Techniques Used-automobile tire retaining wall

General Design Revetment consists of used tires fill with stone. Tires were unattached and laid horizontally in a stepped manner back from the toe of bank

Project Length 150 ft; Construction Cost $ 0 Mo/Yr Completed 1972
landowner used free materials

(5) Maintenance

Experienced Flows (Stage, cfs, Date) 386 ft NGVD. 50,000 cfs, 1 July 1973 (est)

Repairs and Costs (Item, Cost, Data) Initially tires were realigned annually, However, have since stabilized and only require minor maintenance, usually in spring.

Comments: Material cost minimal. Construction and repairs time-consuming

(6) Performance Observations and Summary

Monitoring Program Semiannual (spring and fall)

Documentation Sources Photographs and trip reports

Project Effect on Stream Regime Negligible

Project Effect on Environment Negligible

Successful Aspects Revetment has remained in place and there has been no significant erosion. Revetment was low cost and has worked very well

Unsuccessful Aspects None

General Evaluation No signs of significant erosion were observed during visits Project in generally good condition.

Recommendations This form of revetment is ideal as a self-help measure which a landowner can undertake on his own.

(7) Additional Information, Comments, and Summary

Map No. 24. Since placement costs are high this form of protection is best undertaken by a landowners own available labor resources.

Attached Items.

24 - 1 - Project summary and location

24 - 2 - Initial work and site map

24 - 3 - Plan and cross section

24 - 4 - Low and Normal pools

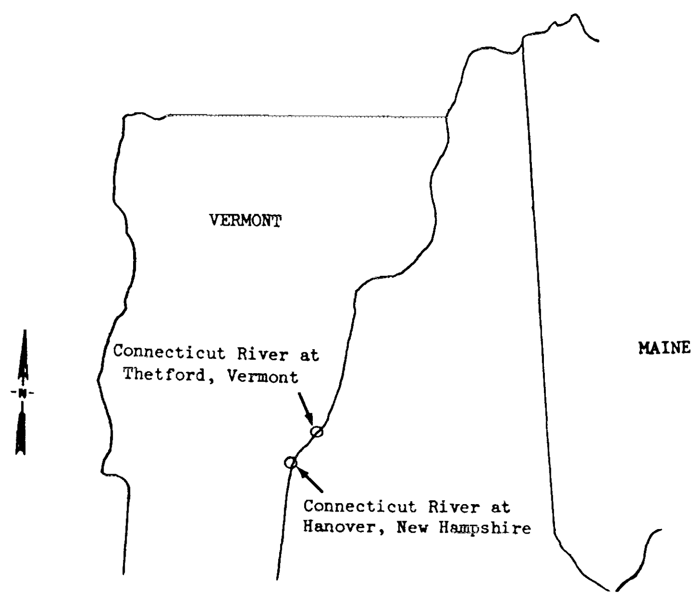
24 - 5 - Initial inspection photographs

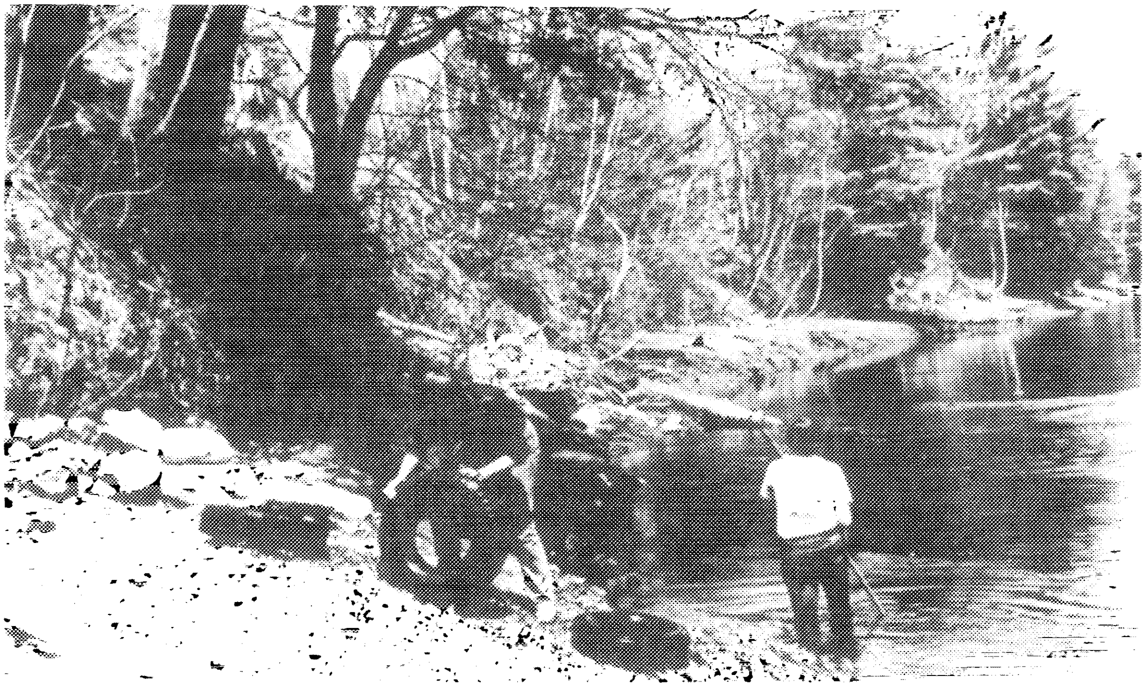
24 - 6 - Final inspection Photographs

Connecticut River

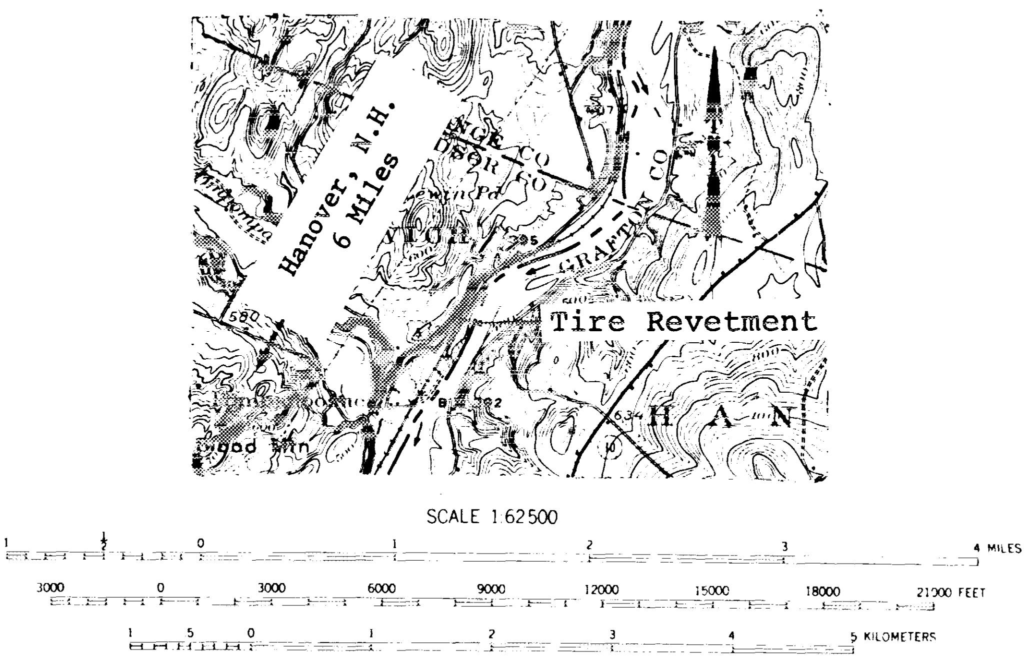
at Thetford, Vermont

In summer 1972, private landowners constructed a 150-ft-long used-tire revetment on the right bank of the Connecticut River. Height of the protection ranged from three to fourteen layers of tires. Each tire was filled with small stones and tamped. At the time of the 1978 inspection, the revetment was intact, and a good stand of vegetation had become established on the upper bank. Minor structural damage was noted in a few places, including undercutting of tires at the upstream end of the revetment, which has resulted in the sagging of some tires and the spilling of fill material. There has also been some displacement of tires due to impact of ice cakes and heavy overbank drainage. Additional tires have been added to maintain the same top elevation. The New England Division, CE, has recommended that holes be drilled in the sidewalls to prevent flotation, that tires be tied together and anchored to the bank, that tires be stepped back 6 to 12 inches with each row, and that the space between the tires and bank be filled with earth or stone to prevent water or ice flow behind the structure.



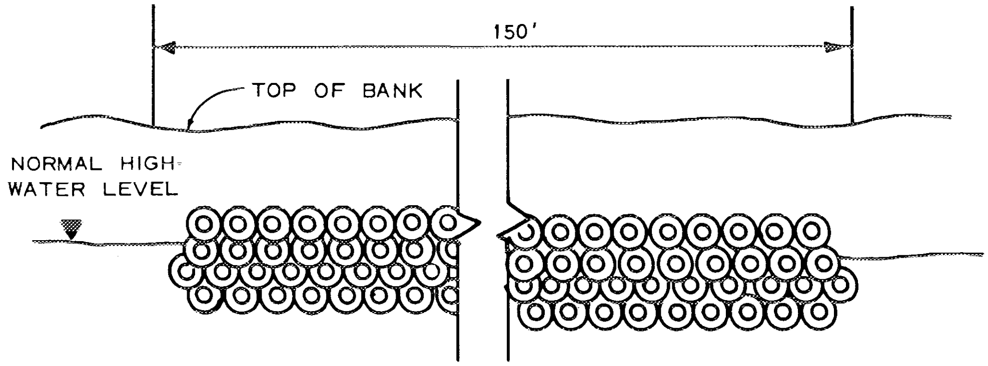


Initiation of used-automobile tire placement in the spring of 1972, Connecticut River at Thetford, Vt. Note eroded bank in background. The Allen residence is located approximately 50 ft landward from the top bank. View is upstream

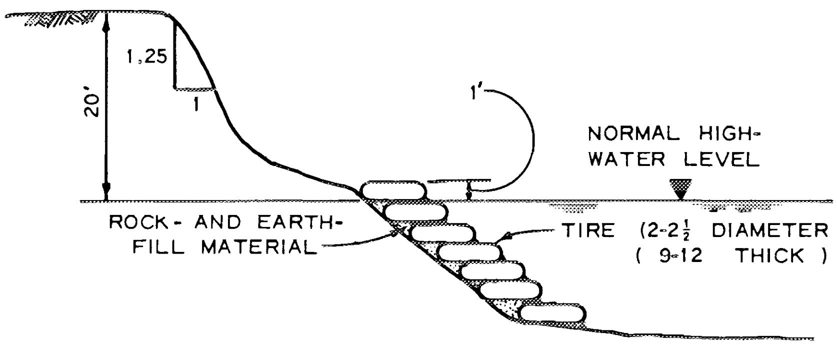


Connecticut River at Thetford, Vt. (Source: USGS 1:62,500 topographic quadrangle map for Mt. Cube, N. H.-Vt., 1931)

ITEM 24-2



PLAN VIEW



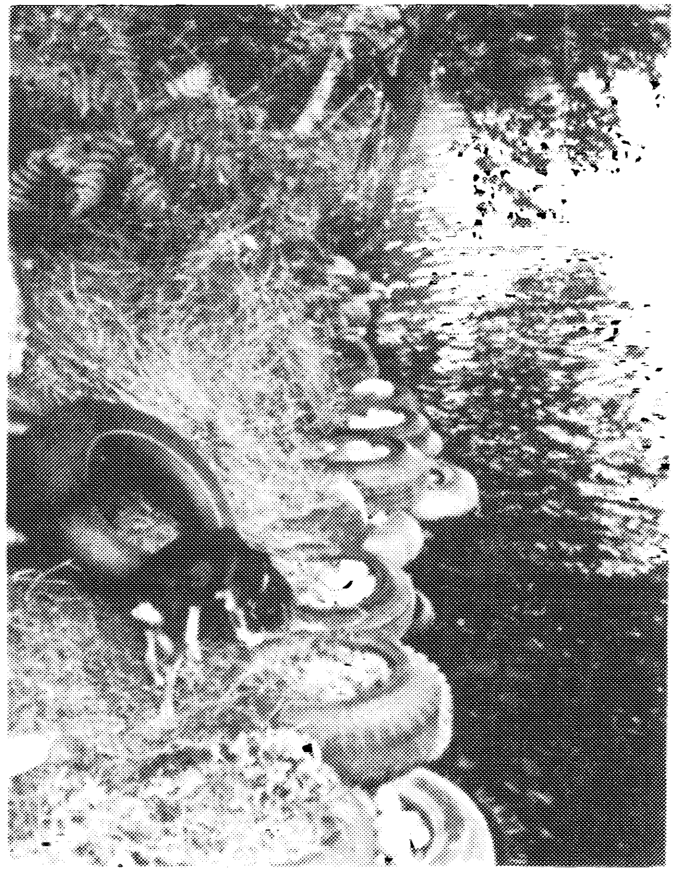
CROSS SECTION

Plan and cross-sectional views of used-automobile tire revetment, Connecticut River at Thetford, Vt. (diagram furnished by New England Division)

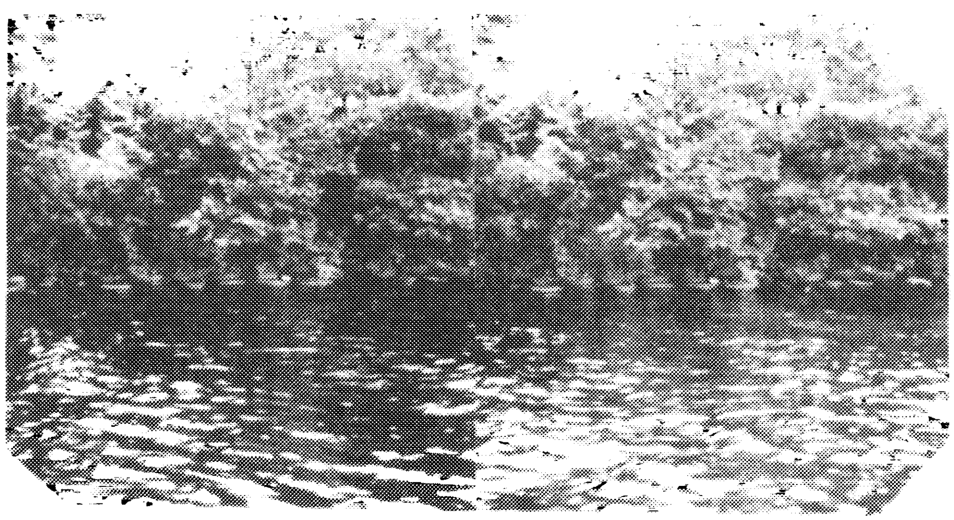
ITEM 24-3

Completed revetment shown at low water, Connecticut River at Thetford, Vt. View is upstream

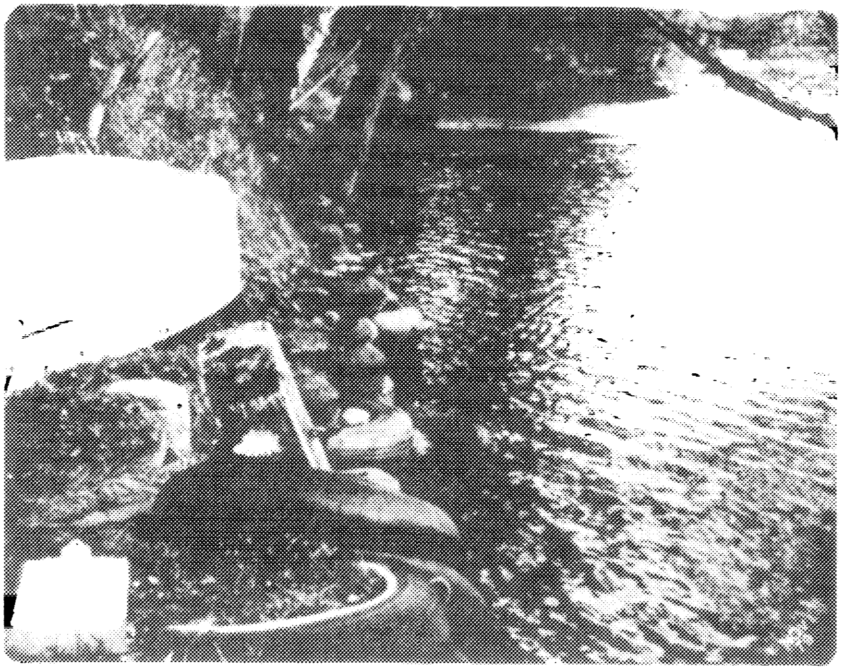
At the time of the inspection visit, vegetation had become well established above the revetment, Connecticut River at Thetford, Vt. View is downstream (26 July 1978)



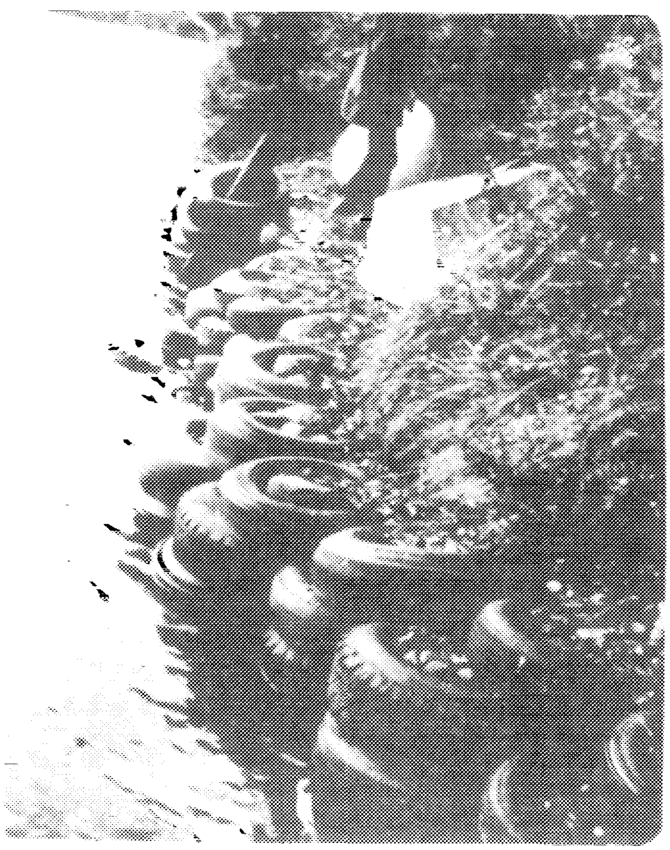
The majority of the used automobile tires have remained in place, although minor realignment has been required, Connecticut River at Thetford, Vt. View is upstream (26 July 1978)



Stereoscopic view of used automobile tire revetment taken during inspection visit, Connecticut River at Thetford, Vt. (26 July 1978)



Upstream view of used automobile tire revetment of right bank of the Connecticut River at Thetford, VT. 1980



Downstream view of used automobile tire revetment on right bank of the Connecticut River at Thetford, VT. 1980

ITEM 24-6

CONNECTICUT RIVER
TURNERS FALLS POOL, MASSACHUSETTS

Streambank Erosion Control Evaluation and Demonstration Act of 1974
Section 32 Program - Work Unit 2

EVALUATION OF EXISTING BANK PROTECTION WORKS

(1) Location

Stream Connecticut River River Mile 126.4-136.1 Side Both

Local Vicinity Turner's Falls Pool Lat N42°37' Long W72°29'

At/Nr City Northfield County Franklin State MA Cong Dist 1

CE Office Symbol NED Responsible Agency Northeast Utilities

Site Map Sources USGS topographic quadrangle maps for Northfield Turners Falls, MA 1976

Land Use Information Sources Northeast Utilities

(2) Hydrology at or Near Site

Stage Range 175 to 216 ft; Period of Record 1915 to 1980.

Discharge Range very small to 210,000 cfs; Velocity Range very small to 3-5 fps

Sediment Range ukn to --- tpd; Period of Record 19 - to 19 -.

Bank-full Stage ukn ft; Flow ukn cfs; Average Recurrence Interval ukn yr

Bank-full Flow Velocity: Average ukn fps; Near Bank ukn fps

Comments Site is located behind Turners Falls Dam a "run of river" hydro facility. Site is subject to daily water-surface fluctuations of about 3.5 feet.

(3) Geology and Soil Properties

Bank (USCS) Sandy silt to medium/fine sand Bed (USCS) Sandy silt to med/fine sand

Data Sources Corps of Engineers

Groundwater Bank Seepage None observed

Overbank Drainage Observed at several locations in Turners Falls Pool

Comments

(4) Construction of Protection

Need for Protection To prevent streambank erosion

Erosion Causative Agents Steep slopes, pool & groundwater fluctuations, wave action, river velocity, freeze-thaw on cohesionless soil, ice attack.

Protection Techniques Tree clearing, riprapping, and hydroseeding.

General Design Trees were cut then removed by helicopter. A slurry consisting of a mixture of grass and shrub seeds was applied. Selected toe areas were riprapped

Project Length 9 miles ft; Construction Cost $ * Mo/Yr Completed 1978*

* See attached Item 25-1 for above information.

(5) Maintenance

Experienced Flows (Stage, cfs, Date) 194 ft NGVD, 82,400 cfs, 15 March 1977

Repairs and Costs (Item, Cost, Data) None to date

Comments:

(6) Performance Observations and Summary

Monitoring Program Semiannual inspections (spring and fall)

Documentation Sources Photographs and trip reports

Project Effect on Stream Regime Negligible

Project Effect on Environment Has restored vegetative cover to major sections of banks. Many trees lining the bank have been removed.

Successful Aspects Areas with riprap are intact with no signs of erosion to date.

Unsuccessful Aspects Areas involving tree removal and hydroseeding without riprap on steep slopes do not appear too successful. Better success on flatter natural slopes

General Evaluation Areas involving tree removal and hydroseeding alone are in poor to fair condition. Riprap revetment was in good condition with no erosion.

Recommendations Riprapped reaches working quite well. Hydroseeding of natural banks alone is only a marginal short-term solution.

(7) Additional Information, Comments, and Summary

Map No. 25. The work was being conducted by Northeast Utilities. The work will be conducted along several reaches of the river.

Attached Items:

25-1 Project summary and location

25-2 Project vicinity map

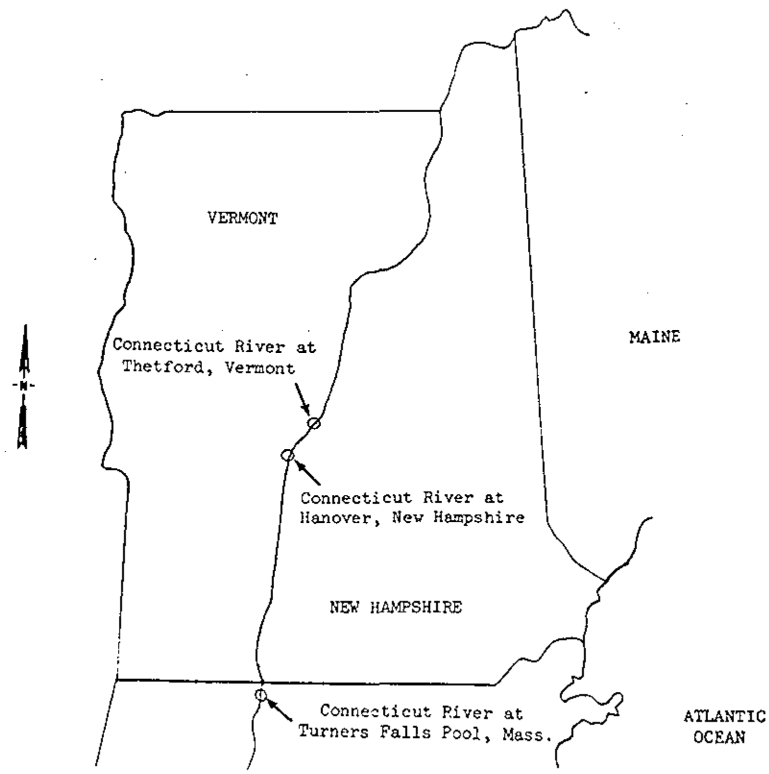
25-3 & 4 Project photographs

Connecticut River

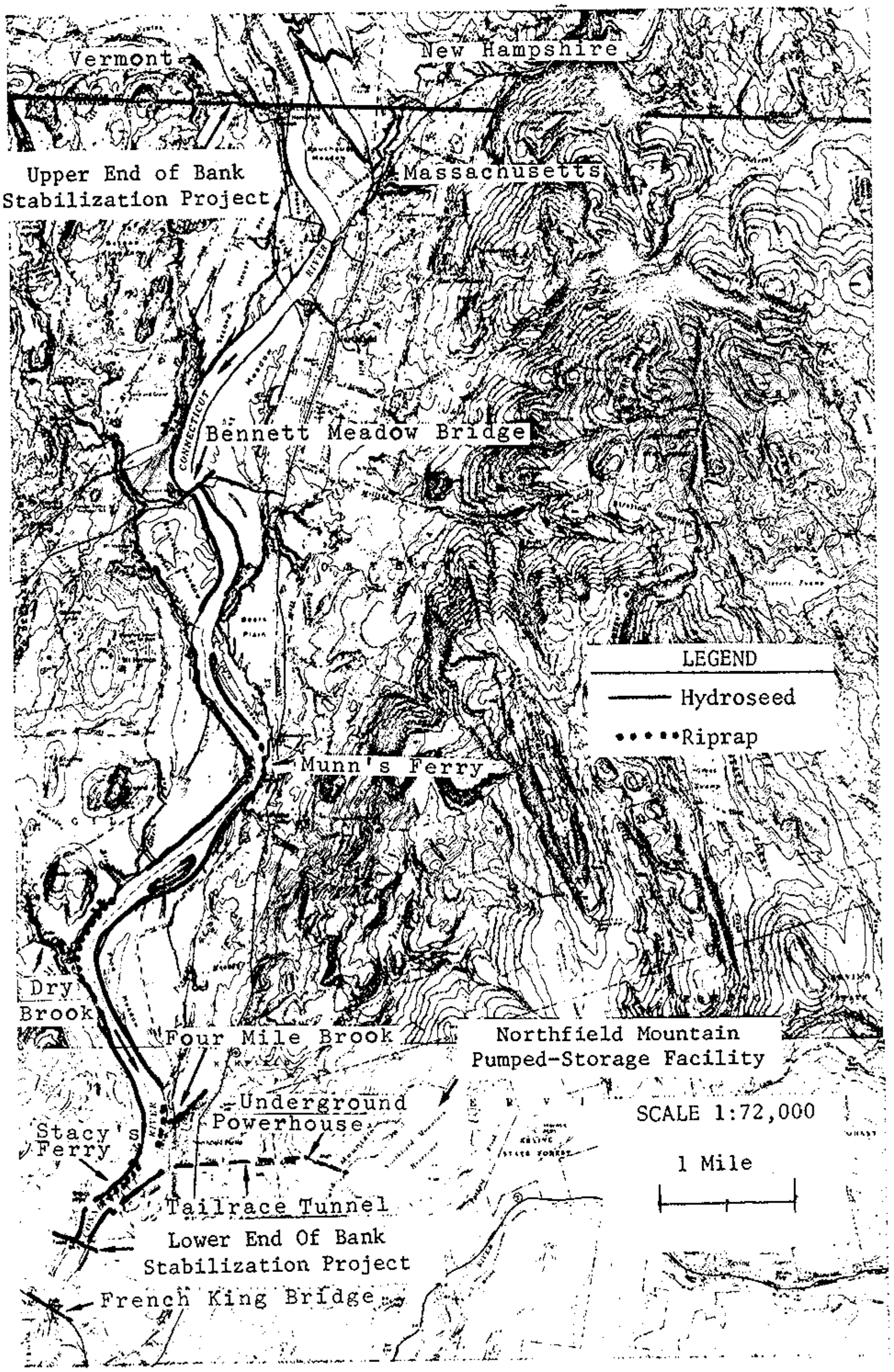
at Turner's Falls Pool, Mass.

In 1973, Northeast Utilities (NU) completed a pumped-storage generation facility and raised Turner's Falls Pool on the Connecticut River 5 ft. By 1975, a number of trees along the bank had toppled into the river as a result of erosion around their root masses, so NU removed all susceptible trees. After the trees were removed and the bank was exposed to sunlight, many volunteer grasses became established and thus enhanced the bank's resistance to erosion. NU hydroseeded 9 miles of banks in 1977 by barge. In those reaches where tree removal and hydroseeding did not effectively control erosion, the banks were riprapped. The stone riprap protection has remained intact since the project was completed; however, there have been no significantly high flows to sufficiently test it. The naturally steep banks that were hydroseeded show definite signs of erosion from overbank drainage, sloughing, and undercutting. The flatter slopes that were hydroseeded have been stabilized.

*Tree removal	20 miles	$350,000	1977
Hydroseeding	9 miles	$ 34,000	1977
Riprap	1.6 miles	$150,000	1978



ITEM 25-1

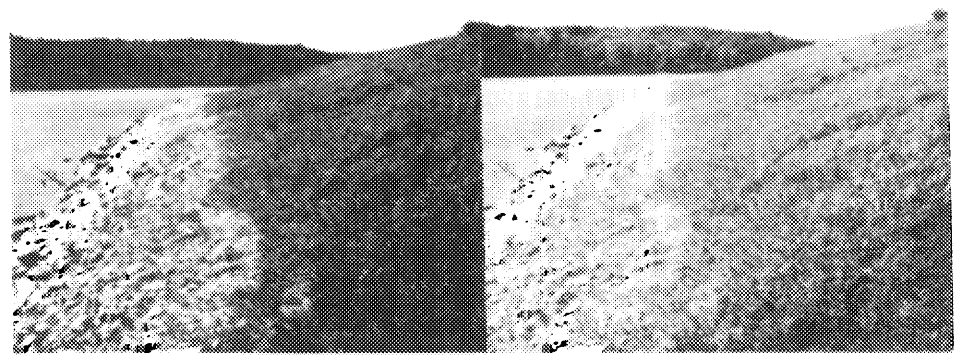


Connecticut River at Turner's Falls Pool, Massachusetts (Source: USGS 1:24,000 topographic quadrangle maps for Northfield, Massachusetts, and Millers Falls, Massachusetts, 1976)

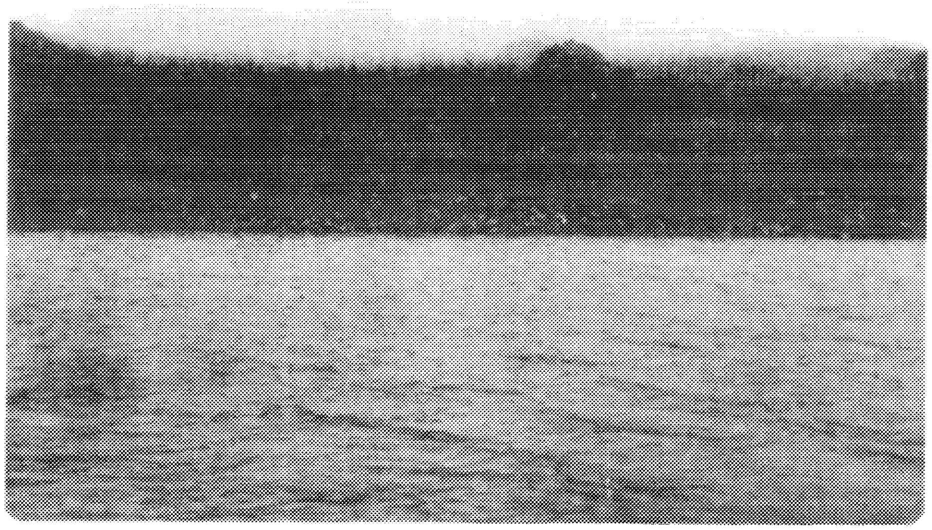
ITEM 25-2

ITEM 25-3

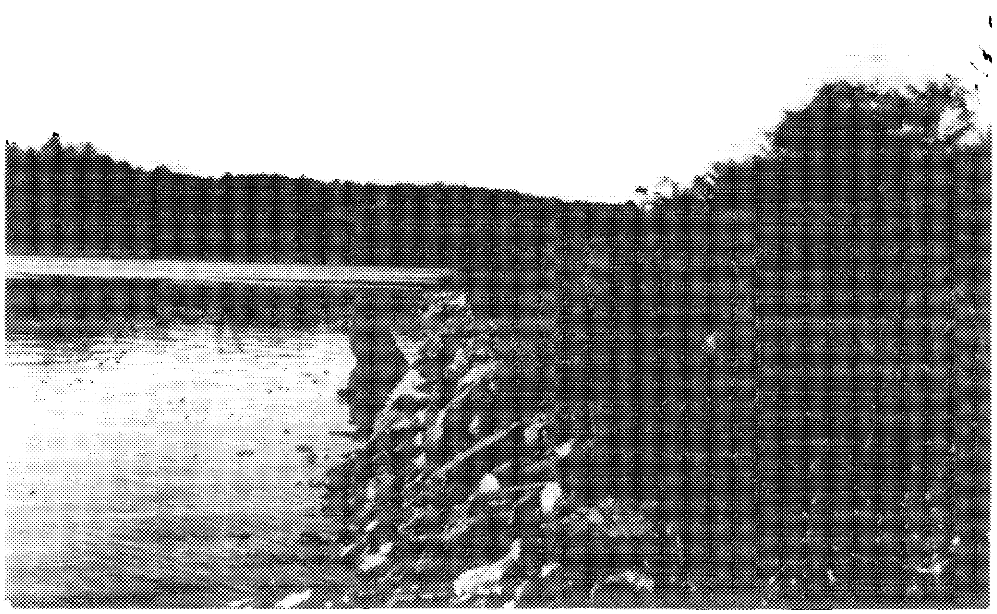
Removal of trees by helicopter (photograph courtesy of Northeast Utilities)



Stereoscopic view of hydroseeded bank with riprap toe protection at Stacy's Ferry, Connecticut River at Turner's Falls Pool. The height from the water surface to the top of the revetment is approximately 4 ft, and to top bank, 12 ft. View is downstream (26 July 1978)



Vegetation had become well established at the Stacy's Ferry site by winter of 1977-78, Connecticut River at Turner's Falls Pool. The height from the water surface to the top of the revetment is approximately 4 ft, and to top bank, 12 ft (photograph courtesy of Northeast Utilities)



Three years after placing riprap and hydroseeding at Stacy's Ferry, Connecticut River at Turner's Falls Pool (Oct 1980)

ITEM 25-4

HAYWARD CREEK
QUINCY, MASSACHUSETTS

Streambank Erosion Control Evaluation and Demonstration Act of 1974
Section 32 Program - Work Unit 2

EVALUATION OF EXISTING BANK PROTECTION WORKS

(1) Location

Stream Hayward Creek River Mile N/A Side Both

Local Vicinity Quincy/Braintree line Lat N42°15' Long W71°

At/Nr City Quincy County Norfolk State MA Cong Dist 11

CE Office Symbol NED Responsible Agency Corps of Engineers

Site Map Sources NED

Land Use Urban

(2) Hydrology at or Near Site

*ungaged watershed

Stage Range ukn to - ft; Period of Record 19 - to 19 -.

Discharge Range ukn to - cfs; Velocity Range - to - fps

Sediment Range ukn to - tpd; Period of Record 19 - to 19 -.

Design Stage 2.5 ft; Flow 33 cfs; Average Recurrence Interval 24 yr

Design Flow Velocity: Average 3-4 fps; Near Bank ukn fps

Comments Channel discharges effectively controlled by upstream Corps flood control storage reservoirs.

(3) Geology and Soil Properties

Bank (USCS) Right bank-landfill Left bank-brown, silty sand gravel with pockets of mud-fill Bed (USCS) Brown silty sandy gravel with pockets of mud fill

Data Sources Project plans and specs.

Groundwater Bank Seepage None observed

Overbank Drainage None observed

Comments None

(4) Construction of Protection

Need for Protection Protect against potential streambank erosion in enlarged creek channel. (Creek connects flood control reservoirs and pressure conduit)

Erosion Causative Agents Excessive velocities on bare bank and channel invert.

Protection Techniques Installation of "Monoslab" concrete blocks.

General Design Monslab grid system on channel invert and both side slopes to top of bank.

Project Length 500 ft; Construction Cost $ 28,500 Mo/Yr Completed 9/77

(5) Maintenance

Experienced Flows (Stage, cfs, Date) Ungaged watershed

Repairs and Costs (Item, Cost, Data) None to date

Comments: Monoslab has worked well and due to nature of material the problems experienced with riprap(i.e. vandalism) have not occurred.

(6) Performance Observations and Summary

Monitoring Program Semiannual inspections (spring and fall)

Documentation Sources Photographs, project plans and specs, and trip reports

Project Effect on Stream Regime Minimal

Project Effect on Environment Beneficial. Vegetation has grown over monoslab very well and aesthetic value greatly enhanced along the streambank.

Successful Aspects Monoslab has successfully stabilized the streambank and has not required maintenance or repair since installation.

Unsuccessful Aspects No major unsuccessful aspects. Some minor settlement of streambank where low-lying drainage areas exist behind channel.

General Evaluation Monoslab has stabilized the bank. No erosion problems since its installation. Vegetation has become well established.

Recommendations Due to lack of high flows, long-term stability unknown, so far, very effective in urban setting because it cannot be removed and thrown into channel as can riprap.

(7) Additional Information, Comments, and Summary

Map No. 26. Monoslab has good durability. Placement of slabs very laborious and would probably prove too expensive along large channel reaches as only one slab can be laid at a time. Erosion had not been a severe problem at this site in the past. Channel work was done to provide uniform entry to conduit and for aesthetic reasons.

Attached Items:

26-1 Project summary and location
26-2 Project site
26-3 Monoslab dimensions
26-4 Project cross sections and photo
26-5 Photos 1 yr after const.
26-6 " 2 yr " "

HAYWARD CREEK

AT QUINCY, MASS.

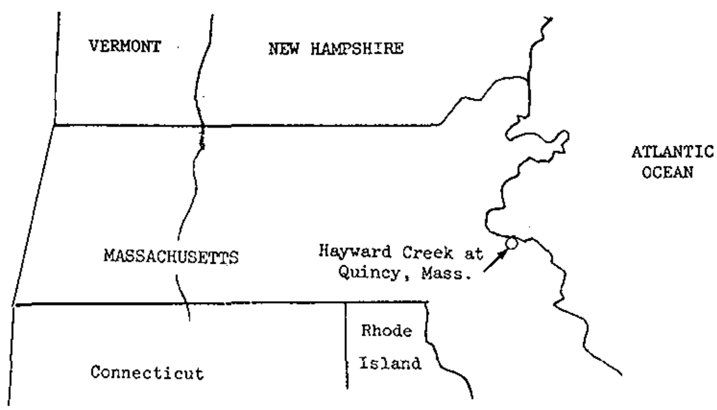
Channel improvement for Hayward Creek consisted of a precast cellular block installation (completed in September 1977) to protect the banks and bottom from erosion. The blocks were placed over a sand layer and gravel bedding. Upper banks were seeded and mulched. In July 1979, minor settlement (about 1 in.) was detected on two areas of the bank; however, the settlement has not affected the integrity of the revetment. Grass growth is still sparse but it has been thus far proved adequate for erosion protection. New England Division, CE, has made the following recommendations regarding the use of precast cellular blocks:

a. The blocks should be laid on a uniform slope.

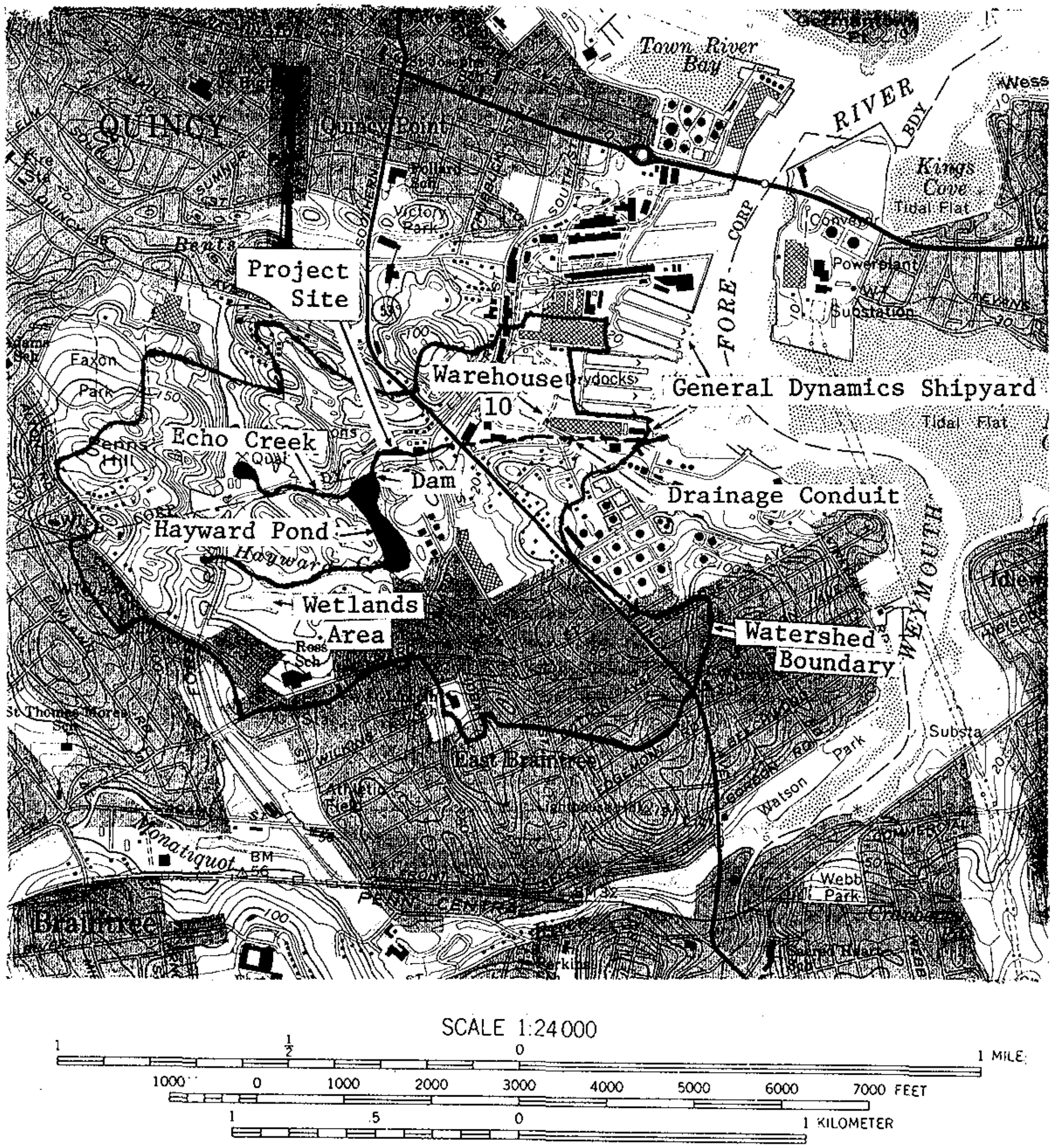
b. A base course, usually consisting of gravel, should be laid prior to block placement. A sand bedding should be used between the gravel and the blocks.

c. The revetment should be extended past the top of the base.

d. Provisions for the drainage of overland flow at the crest of the bank should be included in the project design, preferably an exposed open channel conduit running parallel to the channel alignment with provisions for discharge into the channel at periodic intervals.

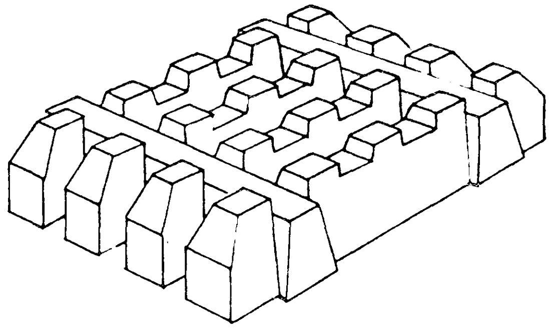


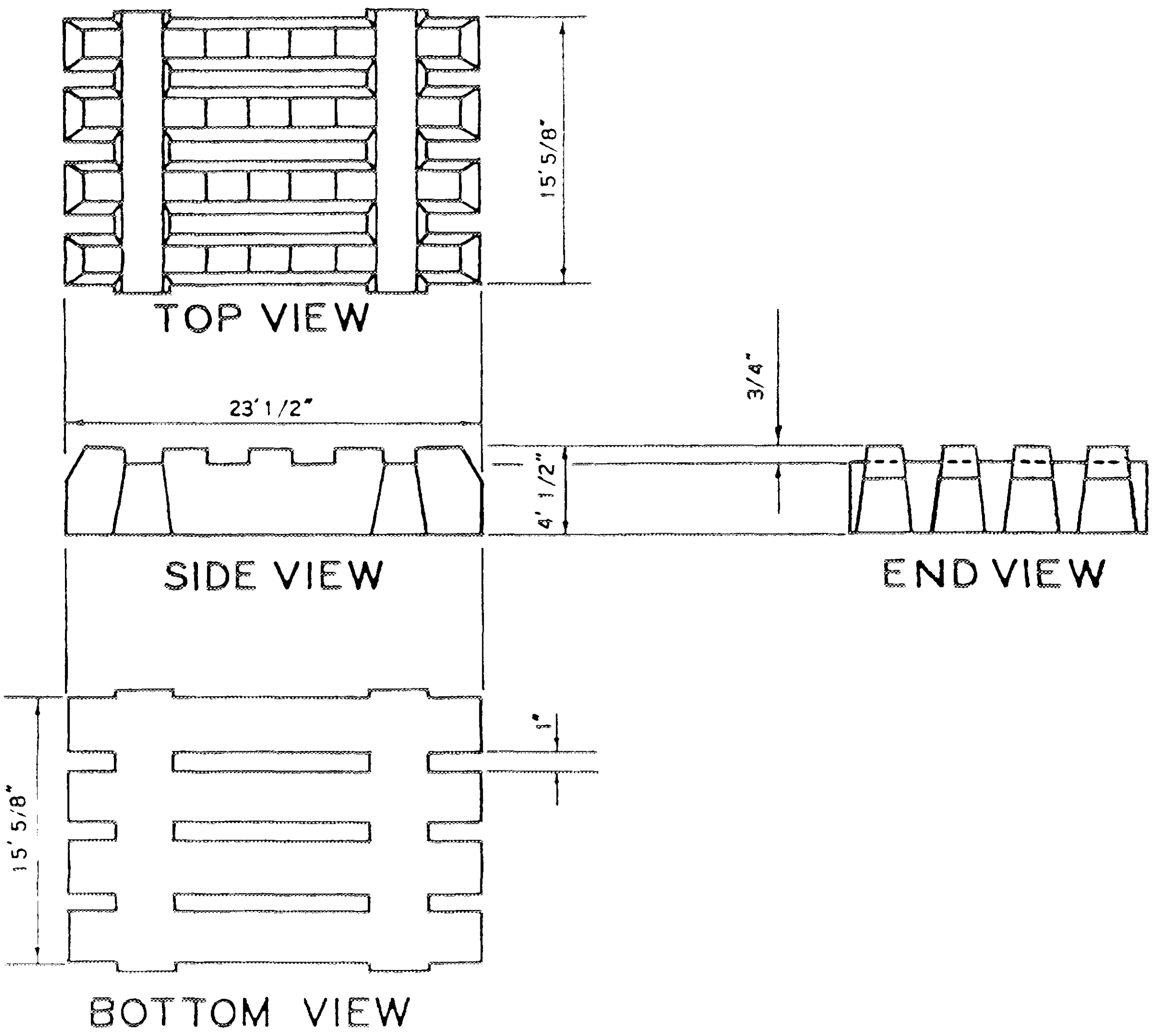
ITEM 26-1



Hayward Creek Basin (Source: USGS 1:24,000 topographic quadrangle map for Weymouth, Mass., 1971)

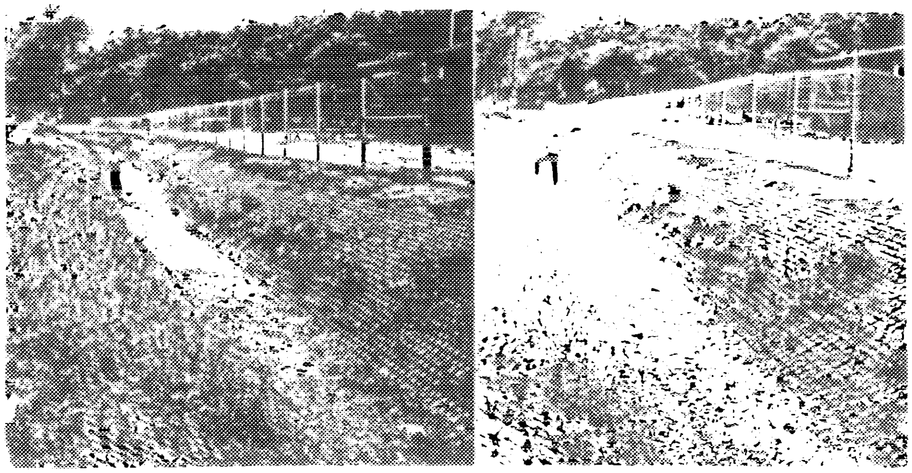
ITEM 26-2



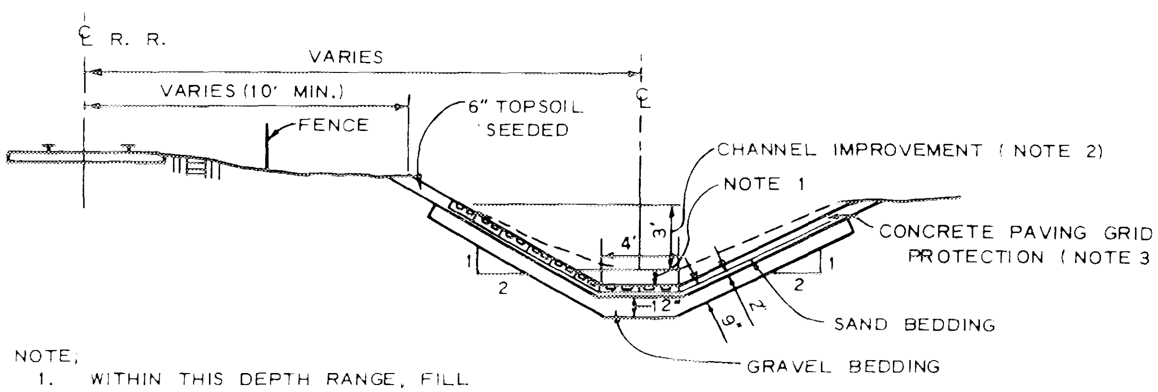


Monoslab dimensional measurements

ITEM 26-3



Upstream stereoscopic view of Monoslab revetment, showing trapezoidal channel cross section, Hayward Creek at Quincy, Massachusetts (25 July 1978)

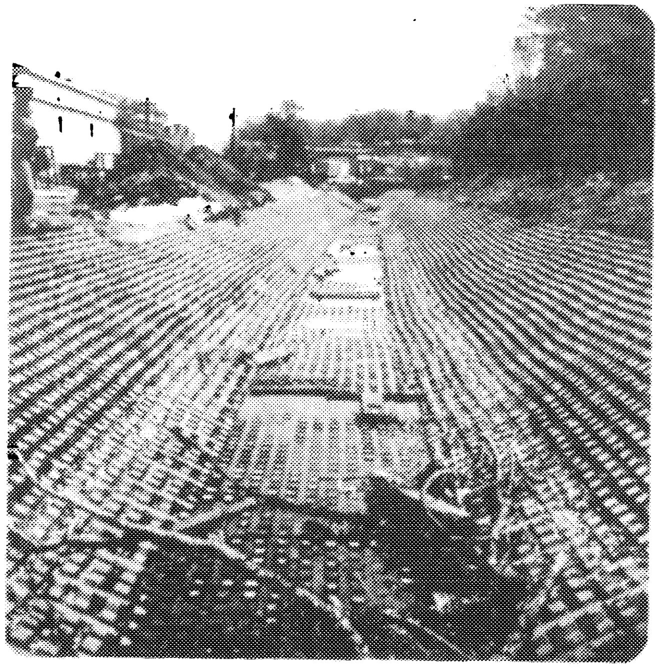


NOTE,

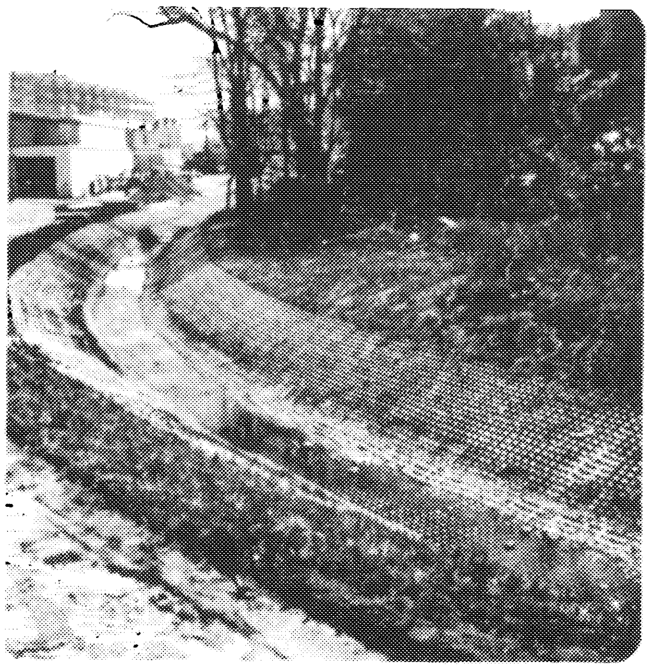
1. WITHIN THIS DEPTH RANGE, FILL IN GRIDS WITH CRUSHED STONE FILL.
2. WITHIN THIS DEPTH RANGE, FILL VOIDS IN GRIDS WITH TOP SOIL MIX. SEED AND MULCH.
3. 6 GRIDS AT 1.5' ON EACH SLOPE.

Cross-sectional view of Monoslab revetment, Hayward Creek at Quincy, Massachusetts

ITEM 26-4



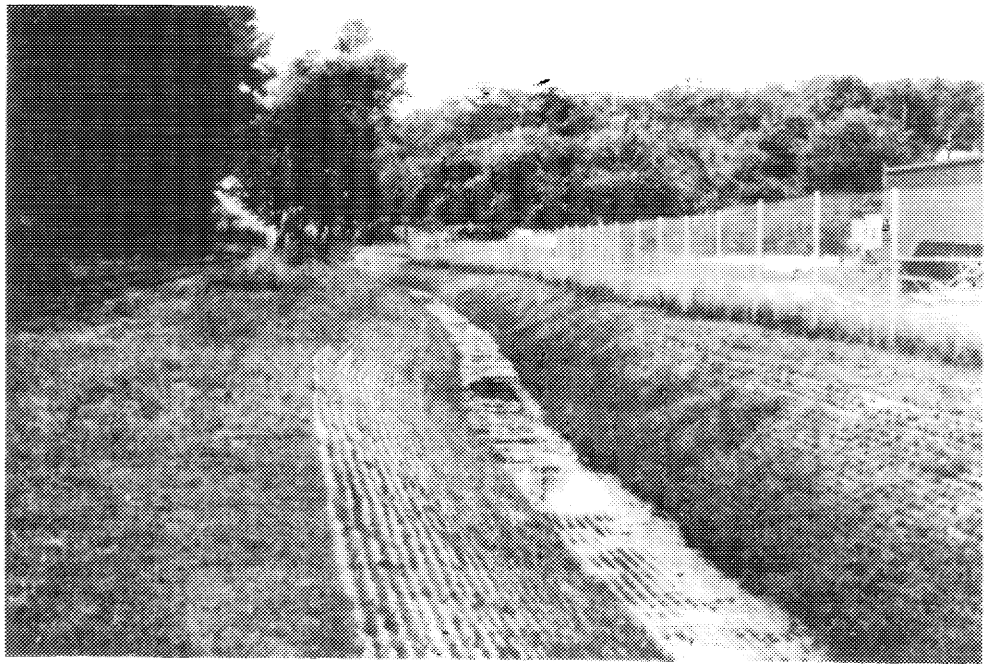
Looking downstream at Monoslab revetment, Hayward Creek at Quincy, Massachusetts (photograph furnished by New England Division, July 1978)



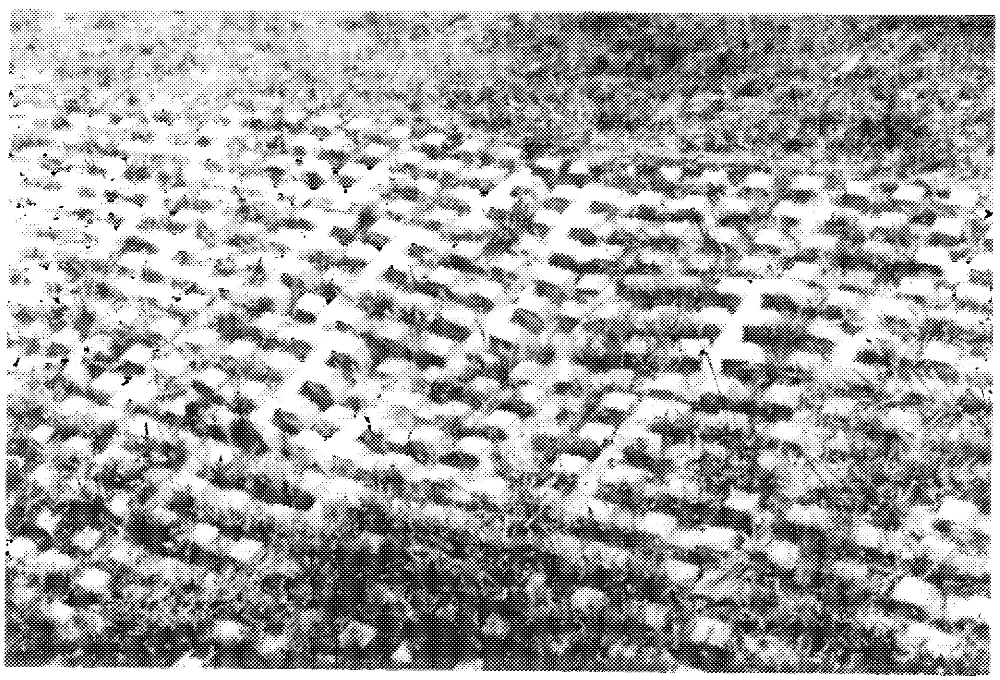
Upstream view of Monoslab revetment, showing trapezoidal channel cross section, Hayward Creek at Quincy, Massachusetts (25 July 1978)

PHOTOGRAPHS OF HAYWARD CREEK ONE YEAR AFTER CONSTRUCTION

ITEM 26-5



Looking upstream from Sta 1+25



Settlement of upper right slope at Sta 3+50

MONOSLAB REVETMENT TWO YEARS AFTER CONSTRUCTION
HAYWARD CREEK AT QUINCY, MASSACHUSETTS
(SEPTEMBER 1980)

ITEM 26-6